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(71)出願人　000004581
日新製鋼株式会社
東京都千代田区丸の内３丁目４番１号

(72)発明者　平松　昭史
広島県呉市昭和町11番１号　日新製鋼株式会社技術研究所内

(72)発明者　大久保　直人
広島県呉市昭和町11番１号　日新製鋼株式会社技術研究所内

(74)代理人　100092392
弁理士　小倉　亘

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(54)【発明の名称】　高速熱処理性及び熱処理後の疲労特性に優れた低合金鋼鋼板

(57)【要約】
【目的】　高密度エネルギビーム照射による熱処理性，熱処理後の疲労特性を改善し、加工性も良好な低合金鋼鋼板を提供する。
【構成】　この低合金鋼鋼板は、Ｃ：０．１５～０．５０%，Ｓｉ：０．３０%以下，Ｍｎ：０．３～１．０%，Ｐ：０．０３%以下，Ｓ：０．０１%以下，Ｔｉ：０．０１～０．１５%，Ｂ：０．０００５～０．００５０%，Ｎ：０．０１%以下，Ａｌ：０．０２～０．１０%を含み、［%Ｐ］≦６×［%Ｂ］＋０．００５を満足する組成をもち、フェライトとパーライト又はベイナイトとの混合組織若しくはベイナイト組織を呈し、表面粗さがＲａ≦５μｍに調整されている。

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【特許請求の範囲】

【請求項１】 Ｃ：０．１５～０．５０重量%，Ｓｉ：０．３０重量%以下，Ｍｎ：０．３～１．０重量%，Ｐ：０．０３重量%以下，Ｓ：０．０１重量%以下，Ｔｉ：０．０１～０．１５重量%，Ｂ：０．０００５～０．００５０重量%，Ｎ：０．０１重量%以下，Ａｌ：０．０２～０．１０重量%を含み、残部が実質的にＦｅで、［%Ｐ］≦６×［%Ｂ］＋０．００５を満足する組成をもち、フェライトとパーライト又はベイナイトとの混合組織若しくはベイナイト組織を呈し、表面粗さがＲａ≦５μｍに調整されている高速熱処理性及び熱処理後の疲労特性に優れた低合金鋼鋼板。

【請求項２】 Ｃ：０．１５～０．５０重量%，Ｓｉ：０．３０重量%以下，Ｍｎ：０．３～１．０重量%，Ｐ：０．０３重量%以下，Ｓ：０．０１重量%以下，Ｔｉ：０．０１～０．１５重量%，Ｂ：０．０００５～０．００５０重量%，Ｎ：０．０１重量%以下，Ａｌ：０．０２～０．１０重量%，Ｃｒ：０．５重量%以下を含み、残部が実質的にＦｅで、［%Ｐ］≦６×［%Ｂ］＋０．００５を満足する組成をもち、フェライトとパーライト又はベイナイトとの混合組織若しくはベイナイト組織を呈し、表面粗さがＲａ≦５μｍに調整されている高速熱処理性及び熱処理後の疲労特性に優れた低合金鋼鋼板。

【発明の詳細な説明】

【０００１】

【産業上の利用分野】本発明は、電子ビーム等の高密度エネルギビームを照射して鋼板表層部を加熱した後で自己冷却させることにより表層に硬化層を形成する急速熱処理に適し、熱処理後の疲労特性に優れた低合金鋼鋼板に関する。

【０００２】

【従来の技術】自動車搭載用機械部品等では、強度，疲労特性，耐摩耗性を確保するため普通鋼に浸炭，窒化等の硬化処理を施し、或いは特殊鋼を焼入れ焼戻しして使用することが一般的であった。近年では、コスト低減を図るため、強度，疲労特性，靭性，耐摩耗性等が要求される部位のみを局部熱処理する方法が採用されている。局部熱処理としては、必要個所を高周波誘導加熱する方法，高密度エネルギビームを照射して加熱する方法等が採用されている。高密度エネルギビームを用いた熱処理法は、特に複雑形状をもつ部品の必要最小限の部位のみを熱処理できる長所をもっている。

【０００３】高密度エネルギビームを用いた熱処理では、適用する部品や部位に応じて素材の加工性及び強度を最適化すると共に、高密度エネルギビーム照射された熱処理部に所望の強度及び用途に応じた疲労特性や耐摩耗性等を付与することが要求される。素材の加工性に関しては、従来加工性に難点があった炭素鋼でも加工技術の進歩に伴って、加工形態によっては球状炭化物をもつ

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組織に比較して硬質のベイナイト組織や変形能の低いパーライト組織であっても加工可能になってきている。

【０００４】しかし、パーライト組織をもつ鋼板の加工性は依然として低く、球状化炭化物組織をもつ鋼板ほどの加工性を必要としないまでも、極力加工性を改善することが要求される。更に、高密度エネルギビームを用いた熱処理性，熱処理後の疲労特性等の材料特性を向上させる必要がある。また、加工の厳しい用途で特殊鋼を使用する場合には、球状化炭化物組織とすることにより加工性を向上させると共に高密度エネルギビーム照射を利用した熱処理性を向上させることが必要である一方で、曲げ加工や軽度の絞り加工，張出し加工，バーリング加工等の場合には加工性がさほど重要視されず、むしろ高密度エネルギビームによる熱処理性の向上や熱処理後の疲労特性の向上等が要求される。更に、高密度エネルギビーム照射で加熱された熱処理部が高強度化されるため、疲労特性や耐摩耗性の観点から表面を極力平滑な状態にする必要がある。

【０００５】高密度エネルギビーム照射で鋼板表面に硬化層を形成する方法が特開平１０－１２１１２５号公報に紹介されている。この方法では、高密度エネルギビームとして電子ビームを用い、熱処理時の溶融・凝固部及び熱影響部の深さ，換言すると硬化層の深さを確保している。対象鋼種は、Ｓ５０Ｃ，Ｓ１０Ｃ等の炭素鋼，ＳＮＣＭ，ＳＣＲ，ＳＣＭ等の合金鋼，ＳＫ，ＳＫＳ等の工具鋼といった比較的一般的な鋼種であり、高密度エネルギビーム照射による熱処理性や熱処理前の加工性・成形性を考慮した鋼種ではない。また、高密度エネルギビーム照射による溶融部の幅，加工速度に応じて高密度エネルギビームの出力，照射時間を最適化することにより、鋼板表面の波打ちを抑制し、溶融深さに影響される表面処理部の表面状態を良好に維持することも開示されている。ところが、高密度エネルギビームを用いた熱処理では、本発明者等による調査・研究の結果から波打ち以外にもクレータ状の表面欠陥が生じ、性能を劣化させることが明らかになった。

【０００６】高密度エネルギビームとしてレーザビームを用い、板厚方向に貫通する熱処理を施す方法も知られている（特開平６－７３４３８号公報，特開平６－７３４３９号公報，特開平６－７３４４０号公報，特開平６－７３４４１号公報，特開平６－７３４４２号公報，特開平６－７３４４３号公報）。たとえば、特開平６－７３４４０号公報では、パーライト又はセメンタイトとフェライト組織をもつ鋼板について合金成分の規定により加工性と強度上昇量のバランスを維持しつつ、レーザビーム照射による熱処理が可能な鋼板が紹介されている。また、特開平６－７３４３８号公報では、ベイナイト及びフェライト組織をもつ鋼板の合金成分を調整することにより、加工性と強度上昇量とのバランスを図ったレーザビーム照射による熱処理性を改善している。しかし、

何れもレーザビーム照射後の表面状態も明らかでなく、レーザビーム照射後の材料特性に関しては強度が取り上げられているが疲労特性については開示されていない。

【０００７】

【発明が解決しようとする課題】このように、従来開示されている高密度エネルギビーム照射を利用した熱処理では、溶融・凝固部及び熱影響部の深さ（硬化層の深さ）をより大きくし、溶融深さに影響される表面処理部を良好な表面状態に保ち、更に熱処理後の疲労特性に優れた鋼板に関しては十分に明らかにされていない。そこで、本発明は、高密度エネルギビームの照射により生じる硬化層の深さをより大きくし、溶融深さに影響される表面処理部の表面状態を良好に維持し、更に熱処理後の疲労特性に優れた鋼板を提供することを目的とする。

【０００８】

【課題を解決するための手段】本発明の低合金鋼鋼板は、その目的を達成するため、Ｃ：０．１５～０．５０重量%，Ｓｉ：０．３０重量%以下，Ｍｎ：０．３～１．０重量%，Ｐ：０．０３重量%以下，Ｓ：０．０１重量%以下，Ｔｉ：０．０１～０．１５重量%，Ｂ：０．０００５～０．００５０重量%，Ｎ：０．０１重量%以下，Ａｌ：０．０２～０．１０重量%，Ｃｒ：０～０．５重量%を含み、残部が実質的にＦｅで、［%Ｐ］≦６×［%Ｂ］＋０．００５を満足する組成をもち、フェライトとパーライト又はベイナイトとの混合組織若しくはベイナイト組織を呈し、表面粗さがＲａ≦５μmに調整されていることを特徴とする。

【０００９】

【作用】本発明者等は、加工性に優れ且つ高密度エネルギビーム照射による熱処理性及び熱処理後の疲労特性に優れた低合金鋼が得られる条件について種々調査・研究した。高密度エネルギビーム照射による熱処理性は、熱処理で形成される硬化層が板厚方向に深いものほど良好と評価される。硬化層が深いと、耐摩耗性，耐久性が向上し、表面の圧縮残留応力を大きくできるため疲労強度も向上する。そこで、本発明者等は、高密度エネルギビームとして電子ビームを用いて種々の組成をもつ鋼板を熱処理し、合金組成が熱処理性に及ぼす影響を調査した。その結果、一般的な炭素鋼や機械構造用鋼に対して、素材を球状化炭化物組織とするよりもフェライト＋パーライト組織，フェライト＋ベイナイト組織又はベイナイト組織にすることが有効であることを解明した。

【００１０】フェライト＋パーライト組織，フェライト＋ベイナイト組織又はベイナイト組織の鋼板を高密度エネルギビーム照射で熱処理すると、α→γ変態点以上に加熱されるときγ中に固溶する速度は球状炭化物よりもパーライトやベイナイトが速いため硬化層がより深くなる。また、フェライト＋パーライト組織，フェライト＋ベイナイト組織又はベイナイト組織をもつ鋼板では、加工性を劣化させないようにＣ，Ｓｉ，Ｍｎ，Ｃｒ量を調整し、更に適量のＢ添加により焼入れ性を向上させると、一層深い硬化層が形成される。

【００１１】硬化層の表面性状は、素材鋼板の表面粗さに影響される。熱処理前の表面粗さが大きいと、熱処理された鋼板表面にクレータ状の表面欠陥が発生し易くなる。クレータ状表面欠陥の発生は、鋼板表面にある凹部の底が高密度エネルギビーム照射で溶融する際に大気や底に残存していた油脂，汚れ等から生成したガスが巻込まれることに原因があると推察される。クレータ状表面欠陥は、耐摩耗性に悪影響を及ぼすと共に、疲労特性を劣化させる切欠き効果を呈する。本発明者等による研究結果から、素材鋼板の表面粗さをＲａ≦５μmにするとき耐摩耗性や疲労特性に悪影響を及ぼすクレータ状表面欠陥が熱処理後の鋼板表面に発生しないことが判った。

【００１２】疲労特性を微量添加成分で改善する一般的な方策としては、Ｐ及びＢの調整が考えられる。すなわち、粒界に偏析して脆化を促進させるＰ量を低減し、粒界に偏析して粒界を強化するＢを添加すると、疲労特性が向上する。Ｐ量の低減及びＢ添加は、熱処理前の鋼板の加工性にも悪影響を及ぼさない。しかし、Ｐ量の低減は、製鋼段階で経済的に不利になる。そこで、Ｐ量及びＢ量を種々変化させた鋼板を電子ビーム照射で熱処理して曲げ式の疲労試験に供し、疲労限度改善に有効なＰ量とＢ量とのバランスを詳細に調査した。その結果、本発明で規定する成分系においては、単純なＰ量の低減及びＢ添加だけでなく、［%Ｐ］≦６×［%Ｂ］＋０．００５の関係をＰ量とＢ量との間に成立させるとき、加工性に悪影響を及ぼすことなく疲労強度が更に改善されることが判った。

【００１３】一般的な加工性向上の指標としては、硬さや引張強さ等の強度が低いこと，通常の引張試験で得られる伸びが大きいこと等が挙げられる。高密度エネルギビーム照射による熱処理が施される用途では、通常の打抜き性や曲げ加工性に加え、穴拡げ性，精密打抜き性等の局部的な延性が必要とされることが多い。局部的な延性は、本発明者などによる調査・研究の結果から切欠き引張伸びと強い相関関係があることが判った。

【００１４】局部的な延性が要求される精密打抜き加工の良否は、打抜き面における破断面の生成難易度により判断される。破断面の生成は、加工変形中に生じる非常に局部的な欠陥によって敏感に引き起こされるものと考えられる。穴拡げ性では、打抜き加工で局部的に変形した個所に更に局部変形（バーリング加工）が加えられる。したがって、穴拡げ性や精密打抜き性は、局部延性の指標である切欠き引張伸び（El_v値）と強い相関関係をもつ。炭素鋼板では、炭化物（セメンタイト）を起点として生じたミクロボイドの成長（連結）が局部的な欠陥の生成原因に挙げられる。この点、炭素鋼板の穴拡げ性，換言すると切欠き引張伸びの改善には、加工変形時にミクロボイドの生成・成長が可能な限り抑制される

金属組織の調整が重要であると考えられる。他の一般的な加工性の改善に伴って切欠き引張伸びが必ずしも同様に改善されないことは、他の加工性に影響を及ぼさないミクロ的な欠陥が切欠き引張伸びに対し敏感に影響することが原因と推察される。

【００１５】このような考察に基づき種々の実験を繰り返した結果、フェライト＋パーライト組織をもつ鋼板にあってはフェライト及びパーライトを微細化するとき、パーライトを起点として生成したミクロボイドの連結が抑制され、穴拡げ性や精密打抜き性等の局部的な延性、すなわち切欠き引張伸びが顕著に改善されることを確認した。フェライト，パーライトの微細化には、熱延された鋼帯を巻き取る際に好ましくは６００℃以下の低温巻取りが有効である。切欠き引張伸びの改善には、鋼板の成分のうちＣ量及びＭｎ量の低下が有利であるが、Ｃ量，Ｍｎ量の低下は焼入れ性，焼入れ硬さの確保等の熱処理性を劣化させ易い。熱処理性の低下を抑制して切欠き引張伸びを改善するには、適量のＴｉ，Ｂ，Ｃｒ等の添加が有効である。Ｔｉ，Ｂ，Ｃｒ等を添加して成分調整すると、高密度エネルギビーム照射による熱処理性も向上する。

【００１６】以下、本発明鋼板に含まれる合金成分，含有量等を説明する。

Ｃ：０．１５～０．５０重量％

本発明は、Ｃ含有量が０．１５～０．５０重量％の範囲にある中炭素鋼を対象にしている。Ｃは炭素鋼において最も基本となる合金成分であり、Ｃ含有量に応じて焼入れ硬さ，炭化物量等が大きく変動する。Ｃ含有量が低いほど切欠き引張伸びが向上するが、十分な焼入れ硬さを確保するため０．１５重量％以上が必要である。しかし、０．５０重量％を超える過剰量のＣが含まれると、熱延後の靭性が低下し、鋼帯の製造性・取扱い性が悪くなるばかりでなく、焼鈍後に十分な切欠き引張伸びが得られない。したがって、高密度エネルギビーム照射による適度な焼入れ硬さ及び加工性を兼ね備えた鋼板を得る上から、０．１５～０．５０重量％の範囲にＣ含有量を定めた。

【００１７】Ｓｉ：０．３０重量％以下

穴拡げ性，精密打抜き性等の局部的な延性の指標である切欠き引張伸びに影響を与える合金成分であり、０．３０重量％を超える過剰量のＳｉは固溶強化作用によりフェライト又はベイナイトを硬化し、成形加工時に割れ発生の原因となる。また、Ｓｉ含有量の増加に伴って製造過程で鋼板表面にスケール疵が発生し易くなり、鋼板の表面品質を低下させる。

Ｍｎ：０．３～１．０重量％

鋼板の焼入れ性を高め、強靭化にも有効な合金成分である。十分な焼入れ性を得るためには、０．３重量％以上のＭｎが必要である。しかし、１．０重量％を超える過剰量のＭｎが含まれると、フェライト又はベイナイトが硬化し、加工性が低下する。

【００１８】Ｐ：０．０３重量％以下

疲労特性に悪影響を及ぼす成分であるが、Ｂ量とのバランス調整によりある程度まで許容される。しかし、Ｐ含有量が０．０３重量％を超えると、Ｂ量とのバランス調整に拘わらず、延性や靭性を劣化させる傾向が大きくなる。

Ｓ：０．０１重量％以下

ＭｎＳ系介在物を形成する有害成分である。ＭｎＳ系介在物が多くなると切欠き引張伸びが低下するので、Ｓ含有量は可能な限り低いほど好ましい。しかし、フェライト＋パーライトの組織に調整すると、極低Ｓ化の必要はなく、一般的な市販鋼であっても精密打抜き性及び切欠き引張伸びが改善される。しかし、Ｃ含有量を０．５０重量％近くまで上げた鋼板にあっても高い切欠き引張伸びを安定して確保するため、Ｓ含有量の上限を０．０１重量％に規定する。また、非常に優れた切欠き引張伸びをもつ鋼板を安定して得るためには、Ｓ含有量を０．００５重量％以下にすることが好ましい。

【００１９】Ｔｉ：０．０１～０．１５重量％

溶鋼の脱酸調整に使用される成分であり、脱窒作用も呈する。また、鋼中に固溶しているＮを窒化物として固定するため、焼入れ性の改善に必要な有効Ｂ量を高める。更には、焼入れ時の結晶粒粗大化防止に有効な炭窒化物を形成する。これらの作用を安定して得るためには、０．０１重量％以上のＴｉが必要である。しかし、０．１５重量％を超える過剰量のＴｉは、経済的に不利なだけでなく、局部的な延性、すなわち切欠き引張伸びを劣化させる原因にもなる。

Ｂ：０．０００５～０．００５０重量％

極微量の添加で熱処理性を大幅に向上させる作用を呈し、焼入れ硬さを安定して得るために必要な合金成分である。このような作用は、０．０００５重量％以上のＢ含有量で顕著になるが、Ｂ量０．００５０重量％で飽和し、０．００５０重量％を超えるＢを添加しても却って靭性が劣化する。

【００２０】Ｎ：０．０１重量％以下

Ｔｉと結合してＴｉＮとなり、焼入れ時の結晶粒を微細化する作用を呈する合金成分である。しかし、Ｎ含有量が０．０１重量％を超えると、延性が低下する。また、過剰なＮは、Ｂと結合し、焼入れ性の改善に有効なＢ量を消費する。

Ａｌ：０．０２～０．１０重量％

Ａｌは、溶鋼の脱酸剤として使用される成分であり、ＡｌＮとしてＮを固定する作用も呈する。このような作用は、０．０２重量％以上のＡｌ含有量で顕著になる。しかし、鋼中のＡｌ量が０．１０重量％を超えると、鋼の清浄度が損われ、鋼板に表面疵が発生し易くなる。

Ｃｒ：０．５重量％以下

必要に応じて添加される合金成分であり、焼入れ性を改

善すると共に、焼戻し軟化抵抗を大きくする。しかし、０．５重量％を超える過剰量のＣｒを添加すると、切欠き引張伸びや一般的な加工性が低下する傾向がみられる。

【００２１】

【実施例１】表１に示す組成の鋼を溶製した。鋼Ａ～Ｄは、本発明で規定した成分条件及び［％Ｐ］≦６×［％Ｂ］＋０．００５を満足する鋼である。比較鋼Ｅ～Ｋのうち、鋼Ｅは［％Ｐ］≦６×［％Ｂ］＋０．００５を満足するが、Ｃ含有量が本発明で規定した範囲より低くなっている。鋼Ｆは、Ｃ含有量が高く、Ｔｉ，Ｂが添加さ＊＊れていない点で本発明で規定する条件を満足していない。鋼Ｇは、ＪＩＳ鋼種のＳ３５Ｃであり、Ｔｉ，Ｂが添加されていない点で本発明で規定する条件を満足していない。鋼Ｈは、Ｎ量が多く、Ｔｉ，Ｂが添加されていない点で本発明で規定する条件を満足していない。鋼Ｉ及びＪは、［％Ｐ］≦６×［％Ｂ］＋０．００５を満足しない鋼である。鋼Ｋは、Ｃｒ含有量が高く、Ｔｉ，Ｂが添加されていない点で本発明で規定する条件を満足していない。

【００２２】

表１：実施例１で使用した鋼材の種類

鋼種記号	合金成分及び含有量（重量%）										X値	区分
	C	Si	Mn	P	S	Cr	Ti	B	Al	N		
A	0.35	0.05	0.31	0.012	0.005	0.28	0.03	0.0042	0.030	0.0027	0.030	本発明例
B	0.22	0.23	0.53	0.019	0.003	0.45	0.05	0.0049	0.022	0.0030	0.034	本発明例
C	0.45	0.02	0.36	0.010	0.007	0.13	0.03	0.0038	0.032	0.0025	0.028	本発明例
D	0.20	0.06	0.88	0.006	0.004	0.34	0.11	0.0008	0.027	0.0032	0.010	本発明例
E	0.10	0.19	0.43	0.011	0.006	—	0.02	0.0024	0.018	0.0030	0.019	比較例
F	0.65	0.25	1.23	0.010	0.005	—	—	—	0.026	0.0030	—	比較例
G	0.34	0.21	0.69	0.012	0.008	—	—	—	0.023	0.0029	—	比較例
H	0.45	0.24	0.55	0.025	0.012	—	—	—	0.033	0.0280	—	比較例
I	0.34	0.05	0.28	0.028	0.005	0.31	0.02	0.0034	0.031	0.0033	0.025	比較例
J	0.45	0.08	0.44	0.017	0.007	—	0.03	0.0007	0.024	0.0260	0.009	比較例
K	0.35	0.06	0.40	0.013	0.006	0.82	—	—	0.032	0.0025	—	比較例

X値＝６×Ｂ＋０．００５

【００２３】各溶鋼を鋳造して得た鋼塊を熱間圧延し、板厚４．０ｍｍの熱延板とした。熱延時、コイル巻取り温度を変えることにより熱延組織を変化させた。各鋼板から切り出された試験片の表面を番手が異なるエメリー紙で研磨し、表面粗さを変えた試料を用意した。そして、加速電圧６０ｋＶ，ビーム電流７０ｍＡ，ビーム振幅周波数１．５ｋＨｚ，照射スピード４ｍ／分，照射幅１０ｍｍの電子ビーム照射条件下で熱処理した後、熱処理部に発生したクレータ状表面欠陥を目視観察し、単位面積当りのクレータ状表面欠陥発生個数（／ｃｍ^2）を求めた。

【００２４】素材鋼板の表面粗さとクレータ状欠陥発生個数との関係を示す表２にみられるように、表面粗さをＲａ０．２～４．８μｍに調整した試験番号１～８（本発明例）では熱処理部のクレータ状表面欠陥発生個数が０～２個／ｃｍ^2 となっており、良好な表面を呈していた。他方、表面粗さがＲａ５．６～１４．７μｍと粗く調整された試験番号９～１４（比較例）では、熱処理部のクレータ状表面欠陥発生個数が９～１９個／ｃｍ^2 と本発明例に比較して著しく多く、表面不良になっていた。

【００２５】

表２：素材鋼板の表面粗さがクレータ状表面欠陥に及ぼす影響

試験番号	鋼種記号	表面粗さＲａ μm	クレータ状表面欠陥の発生個数 個／ｃｍ^2	区分
1	A	3.8	1	本発明例
2	A	0.2	0	
3	B	4.8	2	
4	B	2.3	0	
5	C	4.4	2	
6	C	2.8	1	
7	D	1.4	0	
8	D	3.0	1	
9	A	6.9	10	比較例
10	A	9.8	15	
11	B	5.6	10	
12	C	6.8	9	
13	C	14.7	19	
14	D	5.9	9	

【００２６】更に、各鋼板から切り出された試験片を、加速電圧６０ｋＶ，ビーム電流７０ｍＡ，ビーム振幅周波数１．５ｋＨｚ，照射スピード４ｍ／分，照射幅１０ｍｍの電子ビーム照射で試験片を熱処理し、熱処理部の断面硬さを測定した。そして、最高硬さの８０％に相当する硬さが得られる位置から試験片表面までの距離を測定し、硬化層の深さとした。また、加速電圧６０ｋＶ，ビーム電流７０ｍＡ，ビーム振幅周波数１．５ｋＨｚ，照射スピード４ｍ／分，照射幅３０ｍｍの条件で試験片の表裏両面を電子ビーム照射した後、平面曲げの両振り疲労試験（周波数２３Ｈｚ）により疲労限度を測定した。

【００２７】表３の調査結果にみられるように、試験番号１５，１６（本発明例）では、ほぼ同じＣ含有量の試験番号２７（比較例，鋼Ｇ）に比較して硬化層が約３５０μｍと深く、疲労特性も優れていた。試験番号１７，１８，２１，２２（本発明例）は、試験番号２７（比較例，鋼Ｇ）のＣ含有量０．３４重量％に比較してＣ含有量がほぼ０．２重量％と低いにも拘わらず、深い硬化層が形成されている。試験番号１９，２０（本発明例）は、ほぼ同じＣ含有量の試験番号２８（比較例，鋼Ｈ）に比較して硬化層が深く、疲労特性も優れていた。

【００２８】試験番号２９，３０（比較例）は、何れも［％Ｐ］≦６×［％Ｂ］＋０．００５の条件が満足されず、それぞれＣ含有量がほぼ同じ試験番号１５，１６（本発明例）及び試験番号１９，２０（本発明例）と同じレベルの硬化層深さをもつが、疲労限度が低くなっている。試験番号２３～２５（比較例）は、それぞれ鋼Ａ～Ｃを球状化炭化物組織にしたものであるが、フェライト＋パーライト組織をもつ試験番号１５～２０（本発明例）に比較すると、硬化層が浅く、疲労限度も低くなっている。試験番号２６では、本発明で規定した下限よりもＣ含有量が少ないため最高硬さが低く硬化層も浅くなっており、実際の使用上で支障を来した。

【００２９】

表３：各鋼板の熱処理性及び熱処理後の疲労特性

試験番号	鋼種記号	熱処理で形成された硬化層		熱処理後の疲労限度	区分
		最高硬さ，　HV0.1	深さ，　μm	N／mm^2	
15	A	623	344	270	本発明例
16	A	627	351	275	本発明例
17	B	523	320	260	本発明例
18	B	530	318	255	本発明例
19	C	683	360	295	本発明例
20	C	681	367	285	本発明例
21	D	523	315	255	本発明例
22	D	528	310	255	本発明例
23	A	620	243	220	比較例
24	B	532	224	205	比較例
25	C	675	264	235	比較例
26	E	340	110	—	比較例
27	G	613	286	225	比較例
28	H	691	321	210	比較例
29	I	625	347	195	比較例
30	J	681	362	195	比較例

【００３０】更に、熱延後の巻取り温度を種々変化させ、巻取り温度が鋼板の切欠き引張伸びに及ぼす影響を調査した。切欠き引張試験では、ＪＩＳ　５号試験片の平行部長手方向中央位置における幅方向両側に開き角４５度，深さ２ｍｍのＶノッチを形成した試験片を用いて引張り試験した。そして、Ｖノッチを含む標点間距離５ｍｍに対する伸び率を試験片の破断後に求め、得られたＥｌ$_v$値で加工性を評価した。調査結果を表４に示す。試験番号３１〜３８（本発明例）は、鋼Ａ〜Ｄを巻取り温度６００℃以下で熱延したものであり、同一鋼種で巻取り温度が６００℃を超える試験番号３９，４０（本発明例）に比較すると、高いＥｌ$_v$値が示されており、局部延性に優れていることが判る。他方、本発明で規定した成分条件を満足しない鋼Ｇ，Ｈを使用した場合、試験番号４３，４４（比較例）にみられるように巻取り温度が６００℃以下であってもＥｌ$_v$値が低くなっている。また、Ｃ含有量及びＣｒ含有量が多い鋼Ｆ，Ｋを使用し且つ６００℃を超える温度で巻き取った試験番号４５，４６（比較例）では、Ｅｌ$_v$値が２２％，２７％と低く、加工性に劣っていた。

【００３１】

表４：熱延巻取り温度が切欠き引張伸びに及ぼす影響

試験番号	鋼種記号	熱延巻取温度 ℃	切欠引張伸び El_v値 %	区分
31	A	580	38	本発明例
32	A	560	40	
33	B	580	41	
34	B	480	43	
35	C	580	35	
36	C	530	38	
37	D	580	40	
38	D	500	42	
39	A	630	34	
40	B	650	34	
41	C	680	29	
42	D	650	33	
43	G	580	34	比較例
44	H	580	29	
45	F	680	22	
46	K	650	27	

＊【００３２】

【実施例２】表５に示す組成の鋼を溶製した。鋼Ｌ～Ｏは、本発明で規定した成分条件及び［％Ｐ］≦６×［％Ｂ］＋０．００５を満足する鋼である。比較鋼Ｐ～Ｕのうち、鋼Ｐは［％Ｐ］≦６×［％Ｂ］＋０．００５を満足するが、Ｃ含有量が本発明で規定した範囲より低くなっている。鋼Ｑは、Ｃ含有量が高く、Ｔｉ，Ｂが添加されていない点で本発明で規定する条件を満足していない。鋼Ｒは、ＪＩＳ鋼種のＳ３５Ｃであり、Ｔｉ，Ｂが添加されていない点で本発明で規定する条件を満足していない。鋼Ｓは、Ｎ量が多く、Ｔｉ，Ｂが添加されていない点で本発明で規定する条件を満足していない。鋼Ｔ及びＵは、［％Ｐ］≦６×［％Ｂ］＋０．００５を満足しない鋼である。

【００３３】

＊

表５：実施例２で使用した鋼材の種類

鋼種記号	合金成分及び含有量 (重量%)										X値	区分
	C	Si	Mn	P	S	Cr	Ti	B	Al	N		
L	0.36	0.04	0.33	0.011	0.005	0.29	0.02	0.0045	0.030	0.0035	0.032	本発明例
M	0.23	0.25	0.50	0.020	0.003	0.42	0.05	0.0033	0.022	0.0033	0.025	
N	0.48	0.01	0.34	0.009	0.008	0.11	0.03	0.0040	0.038	0.0024	0.029	
O	0.20	0.06	0.88	0.006	0.004	0.47	0.11	0.0008	0.027	0.0032	0.010	
P	0.12	0.33	0.52	0.011	0.006	—	0.05	0.0031	0.020	0.0034	0.024	比較例
Q	0.65	0.25	1.23	0.010	0.005	—	—	—	0.024	0.0030	—	
R	0.35	0.23	0.71	0.013	0.009	—	—	—	0.021	0.0033	—	
S	0.45	0.24	0.55	0.025	0.012	—	—	—	0.033	0.0280	—	
T	0.35	0.06	0.31	0.035	0.006	0.35	0.03	0.0036	0.030	0.0025	0.027	
U	0.45	0.08	0.44	0.017	0.007	—	0.03	0.0007	0.024	0.0260	0.009	

X値＝６×Ｂ＋０．００５

【００３４】各溶鋼を鋳造して得た鋼塊を熱間圧延し、板厚４．０ｍｍの熱延板とした。熱延板を９００℃で均熱１５分保持した後、３００～５００℃で３０分保持してベイナイト組織にした。鋼Ｌ～Ｎの一部については、更に７００℃で均熱２０時間の焼鈍を施し、球状化炭化物組織にした。各鋼板から切り出された試験片の表面を番手が異なるエメリー紙で研磨し、表面粗さを変えた試料を用意した。そして、加速電圧６０ｋＶ，ビーム電流

７０ｍＡ，ビーム振幅周波数１．５ｋＨｚ，照射スピード４ｍ／分，照射幅１０ｍｍの電子ビーム照射条件下で熱処理した後、熱処理部に発生したクレータ状表面欠陥を目視観察し、単位面積当りのクレータ状表面欠陥発生個数（／ｃｍ^2 ）を求めた。

【００３５】素材鋼板の表面粗さとクレータ状欠陥発生個数との関係を示す表６にみられるように、表面粗さをＲａ０．５～４．７μｍに調整した試験番号５１～５８（本発明例）では熱処理部のクレータ状表面欠陥発生個数が０～２個／ｃｍ^2 となっており、良好な表面を呈していた。他方、表面粗さがＲａ５．７～１３．５μｍと粗く調整された試験番号５９～６４（比較例）では、熱処理部のクレータ状表面欠陥発生個数が９～１７個／ｃｍ^2 と本発明例に比較して著しく多く、表面不良になっていた。

【００３６】

表６：素材鋼板の表面粗さがクレータ状表面欠陥に及ぼす影響

試験番号	鋼種記号	表面粗さＲａ μm	クレータ状表面欠陥の発生個数 個／ｃｍ^2	区分
51	L	4.0	2	本発明例
52	L	0.5	0	
53	M	3.3	1	
54	M	2.1	0	
55	N	4.7	2	
56	N	3.6	2	
57	O	1.4	0	
58	O	2.5	0	
59	L	6.0	10	比較例
60	L	9.4	15	
61	M	5.7	9	
62	N	7.8	11	
63	N	13.5	17	
64	O	7.3	9	

【００３７】更に、各鋼板から切り出された試験片を、加速電圧６０ｋＶ，ビーム電流７０ｍＡ，ビーム振幅周波数１．５ｋＨｚ，照射スピード４ｍ／分，照射幅１０ｍｍの電子ビーム照射で試験片を熱処理し、熱処理部の断面硬さを測定した。そして、最高硬さの８０％に相当する硬さが得られる位置から試験片表面までの距離を測定し、硬化層の深さとした。また、加速電圧６０ｋＶ，ビーム電流７０ｍＡ，ビーム振幅周波数１．５ｋＨｚ，照射スピード４ｍ／分，照射幅３０ｍｍの条件で試験片の表裏両面を電子ビーム照射した後、実施例１と同様な疲労試験で疲労限度を測定した。

【００３８】表７の調査結果にみられるように、試験番号６５，６６（本発明例）では、ほぼ同じＣ含有量の試験番号７７（比較例，鋼Ｒ）に比較して硬化層が約３４０μｍと深く、疲労特性も優れていた。試験番号６７，６８，７１，７２（本発明例）は、試験番号７７（比較例，鋼Ｒ）のＣ含有量０．３５重量％に比較してＣ含有量がほぼ０．２重量％と低いにも拘わらず、深い硬化層が形成されている。試験番号７３～７５（比較例）は、それぞれ鋼Ｌ～Ｎを球状化炭化物組織にしたものであるが、ベイナイト組織にした試験番号６５～７０でＣ含有量が同レベルのものと比較すると、最高硬さはほぼ同等であるが、素材強度が低く、しかも硬化層が浅いため、疲労強度が低下していた。試験番号６９，７０（本発明例）は、ほぼ同じＣ含有量の試験番号７８（比較例，鋼Ｓ）に比較して硬化層が３６０μｍと深く、クレータ状の表面欠陥も少ないため、著しく優れた疲労特性を示した。試験番号７９，８０（比較例）は、何れも［％Ｐ］≦６×［％Ｂ］＋０．００５の条件が満足されず、それぞれＣ含有量がほぼ同じ試験番号６５，６６（本発明例）及び試験番号６９，７０（本発明例）と同じレベルの硬化層深さをもつが、疲労限度が低くなっている。試験番号７６（比較例）では、本発明で規定した下限よりもＣ含有量が少ないため最高硬さが低く硬化層も浅くなっており、実際の使用上で支障を来した。

【００３９】

表７：各鋼板の熱処理性及び熱処理後の疲労特性

試験番号	鋼種記号	熱処理で形成された硬化層		熱処理部の疲労限度 N/mm^2	区分
		最高硬さ，HV0.1	深さ，μm		
65	L	624	340	355	本発明例
66	L	617	338	350	
67	M	522	318	285	
68	M	529	316	275	
69	N	671	364	420	
70	N	679	373	430	
71	O	520	329	290	
72	O	518	318	280	
73	L	617	250	220	比較例
74	M	532	239	205	
75	N	668	264	240	
76	P	346	115	—	
77	R	631	277	240	
78	S	682	301	217	
79	T	620	336	230	
80	U	679	365	235	

【００４０】
【発明の効果】以上に説明したように、本発明の低合金鋼鋼板は、合金成分を調整してフェライト＋パーライト混合組織，フェライト＋ベイナイト混合組織又はベイナイト組織とし、高密度エネルギビーム照射による熱処理＊で深い硬化層を形成し、しかも硬化層が形成された熱処理部の表面を良好に維持して熱処理後の疲労特性を向上させている。このようにして、本発明の低合金鋼鋼板は、加工性に優れていることと相俟って自動車搭載用部品を始めとして各種機械分として使用される。

フロントページの続き

(72)発明者　面迫　浩次
広島県呉市昭和町11番１号　日新製鋼株式会社技術研究所内

(72)発明者　秋月　誠
広島県呉市昭和町11番１号　日新製鋼株式会社技術研究所内

CLAIMS

[Claim(s)]
[Claim 1] C: 0.15 - 0.50 % of the weight, Si: 0.30 or less % of the weight, Mn:0.3-1.0 % of the weight, P:0.03 % of the weight or less, S:0.01 % of the weight or less, Ti:0.01-0.15 % of the weight, B:0.0005 - 0.0050 % of the weight, N:0.01 % of the weight or less, and aluminum:0.02-0.10 % of the weight are included. The remainder has substantially the presentation to which it is satisfied with Fe of [%P] <=6x[%B]+0.005. The low-alloy-steel steel plate excellent in the high-speed heat treatability which presents a mixed organization or a bainite texture with a ferrite, a pearlite, or bainite and by which surface roughness is adjusted to Ra<=5micrometer, and the fatigue property after heat treatment.
[Claim 2] C: 0.15 - 0.50 % of the weight, Si: 0.30 or less % of the weight, Mn: Less than [Cr:0.5 % of the weight] is included 0.3 - 1.0 % of the weight, P:0.03 % of the weight or less, S:0.01 % of the weight or less, Ti:0.01-0.15 % of the weight, B:0.0005 - 0.0050 % of the weight, N:0.01 % of the weight or less, and aluminum:0.02-0.10% of the weight. The remainder has substantially the presentation to which it is satisfied with Fe of [%P] <=6x[%B]+0.005. The low-alloy-steel steel plate excellent in the high-speed heat treatability which presents a mixed organization or a bainite texture with a ferrite, a pearlite, or bainite and by which surface roughness is adjusted to Ra<=5micrometer, and the fatigue property after heat treatment.

[Translation done.]

DETAILED DESCRIPTION

[Detailed Description of the Invention]
[0001]
[Industrial Application] After this invention irradiates high density energy beams, such as an electron beam, and heats the steel plate surface section, it is suitable for rapid heat treatment which forms a hardening layer in a surface by carrying out self-cooling, and it relates to the low-alloy-steel steel plate excellent in the fatigue property after heat treatment.
[0002]
[Description of the Prior Art] It was common to perform hardening processing of carburization, nitriding, etc. to plain steel in the machine part for automobile loading, in order to secure reinforcement, a fatigue property, and abrasion resistance, or to have used special steel, carrying out hardening annealing. In recent years, in order to plan cost reduction, the approach of carrying out local heat treatment only of the part where reinforcement, a fatigue property, toughness, abrasion resistance, etc. are demanded is adopted. As local heat treatment, the approach of carrying out high frequency induction heating of the need part, the method of irradiating a high density energy beam and heating it, etc. are adopted. Especially the heat-treating method using a high density energy beam has the advantage which can heat-treat only the necessary minimum part of components with a complicated configuration.
[0003] In heat treatment using a high density energy beam, while optimizing the workability and reinforcement of a raw material according to the components and part to apply, it is required that the fatigue property according to desired reinforcement and a desired application, abrasion resistance, etc. should be given to the heat treatment section by which the high density energy beam exposure was carried out. About the workability of a raw material, even if it is a hard bainite texture and the low pearlite organization of deformability as compared with the organization where carbon steel with a difficulty also has a spheroidal carbide in workability with an advance of a processing technique depending on a processing gestalt conventionally, it is becoming processible.
[0004] However, the workability of a steel plate with a pearlite organization is still low, and although workability like a steel plate with a balling-up carbide organization is not needed, it is required that workability should be improved as much as possible. Furthermore, it is necessary to raise material properties, such as heat treatability using a high density energy beam, and a fatigue property after heat treatment. Moreover, to use special steel for the severe application of processing, while raising workability by considering as a balling-up carbide organization and it is required to raise the heat treatability using a high density energy beam exposure, in the case of bending, slight spinning, bulging, burring, etc., importance is not attached so much to workability, but improvement in the heat treatability by the high density energy beam, improvement in the fatigue property after heat treatment, etc. are required rather. Furthermore, since the heat treatment section heated by the high density energy beam exposure is high-intensity-ized, it is necessary to change a front face into a smooth condition as much as possible from a fatigue property or a wear-resistant viewpoint.
[0005] The approach of forming a hardening layer in a steel plate front face by high density energy beam exposure is introduced to JP,10-121125,A. By this approach, using an electron

beam as a high density energy beam, if it puts in another way in the depth of melting and the coagulation section at the time of heat treatment, and a heat affected zone, the depth of a hardening layer will be secured. An object steel type is a comparatively general steel type called tool steel, such as alloy steel, such as carbon steel, such as S50C and S10C, SNCM, and SCR, SCM, and SK, SKS, and is not a steel type in consideration of the heat treatability by high density energy beam exposure, or the workability and the moldability before heat treatment. Moreover, by optimizing the output of a high density energy beam, and irradiation time according to the width of face of the fusion zone by high density energy beam exposure, and working speed, flapping on the front face of a steel plate is controlled, and maintaining the surface state of the surface treatment section influenced by the melting depth good is also indicated. However, in heat treatment using a high density energy beam, it lenticulated from the result of the examination and research by this invention person etc., crater-like surface discontinuity arose also in except, and it became clear to degrade the engine performance.
[0006] The method of performing heat treatment penetrated in the direction of board thickness is also learned, using a laser beam as a high density energy beam (JP,6-73438,A, JP,6-73439,A, JP,6-73440,A, JP,6-73441,A, JP,6-73442,A, JP,6-73443,A). For example, in JP,6-73440,A, the steel plate in which heat treatment by laser beam exposure is possible is introduced, maintaining the balance of workability and the amount of on-the-strength lifting according to a convention of an alloy content about a steel plate with a pearlite or a cementite, and a ferrite. Moreover, in JP,6-73438,A, the heat treatability by the laser beam exposure aiming at the balance of workability and the amount of on-the-strength lifting is improved by adjusting the alloy content of a steel plate with bainite and a ferrite. However, although the surface state of neither after a laser beam exposure is also clear and reinforcement is taken up about the material property after a laser beam exposure, it is not indicated about a fatigue property.
[0007]
[Problem(s) to be Solved by the Invention] Thus, in heat treatment using the high density energy beam exposure currently indicated conventionally, the depth (depth of a hardening layer) of melting, the coagulation section, and a heat affected zone is enlarged more, and the surface treatment section influenced by the melting depth is maintained at a good surface state, and it is not clarified enough about the steel plate which was further excellent in the fatigue property after heat treatment. Then, this invention enlarges more the depth of the hardening layer produced by the exposure of a high density energy beam, maintains the surface state of the surface treatment section influenced by the melting depth good, and aims at offering the steel plate which was further excellent in the fatigue property after heat treatment.
[0008]
[Means for Solving the Problem] In order that the low-alloy-steel steel plate of this invention may attain the object, C: 0.15 - 0.50 % of the weight, Si: 0.30 or less % of the weight, Mn: 0.3 - 1.0 % of the weight, P:0.03 % of the weight or less, S:0.01 % of the weight or less, Ti:0.01-0.15 % of the weight, B:0.0005 - 0.0050 % of the weight, N:0.01 % of the weight or less, aluminum:0.02-0.10 % of the weight, and Cr:0-0.5 % of the weight are included. The remainder has substantially the presentation which is satisfied with Fe of [%P] <=6x[%B]+0.005, a mixed organization or a bainite texture with a ferrite, a pearlite, or bainite is presented, and it is characterized by adjusting surface roughness to Ra<=5micrometer.
[0009]
[Function] this invention person etc. investigated and studied many things about the conditions from which the low alloy steel which was excellent in workability and was excellent in the heat treatability by high density energy beam exposure and the fatigue property after heat treatment is obtained. It is estimated that what has the deeper hardening layer in the direction of board thickness formed by heat treatment is better as for the heat treatability by high density energy beam exposure. If a hardening layer is deep, abrasion resistance and endurance improve, and since surface compressive residual stress can be enlarged, fatigue strength will also improve. Then, this invention person etc. heat-treated the steel plate which has various presentations, using an electron beam as a high density energy beam, and investigated the effect an alloy presentation affects heat treatability. Consequently, to common carbon steel and steel for

machine structural use, it solved it was effective to make it a ferrite + pearlite organization, a ferrite + bainite texture, or a bainite texture rather than having considered a raw material as a balling-up carbide organization.

[0010] If the steel plate of a ferrite + pearlite organization, a ferrite + bainite texture, or a bainite texture is heat-treated by high density energy beam exposure, when heated more than the alpha->gamma transformation point, since a pearlite and bainite are quicker than a spheroidal carbide, as for the rate which dissolves in gamma, a hardening layer will become deeper. Moreover, in a steel plate with a ferrite + pearlite organization, a ferrite + bainite texture, or a bainite texture, if C, Si, Mn, and the amount of Cr(s) are adjusted so that workability may not be degraded, and hardenability is further raised by B addition of optimum dose, a still deeper hardening layer will be formed.

[0011] The shape of table planarity of a hardening layer is influenced by the surface roughness of a raw material steel plate. If the surface roughness before heat treatment is large, it will become easy to generate crater-like surface discontinuity on the heat-treated steel plate front face. In case the bottom of the crevice in a steel plate front face fuses generating of crater-like surface discontinuity by high density energy beam exposure, it is guessed that a cause is to involve in the gas generated from the fats and oils which remained at atmospheric air or a bottom, dirt, etc. Crater-like surface discontinuity presents the notch effect which degrades a fatigue property while having an adverse effect on abrasion resistance. The research result by this invention person etc. showed not generating on the steel plate front face after the crater-like surface discontinuity which has an adverse effect on abrasion resistance or a fatigue property heat-treating, when setting surface roughness of a raw material steel plate to Ra<=5micrometer.

[0012] Adjustment of P and B can be considered as a general policy which improves a fatigue property of a minute amount addition component. That is, the amount of P which it segregates [amount] to a grain boundary and promotes embrittlement is reduced, and if B which segregates to a grain boundary and strengthens a grain boundary is added, a fatigue property will improve. Reduction and B addition of the amount of P do not have an adverse effect on the workability of the steel plate before heat treatment, either. However, reduction of the amount of P becomes disadvantageous economically in a steel-manufacture phase. Then, the steel plate to which various the amounts of P and the amounts of B were changed was heat-treated by the electron beam exposure, the fatigue test of a bending type was presented, and the balance of the amount effective in a fatigue limit improvement of P and the amount of B was investigated in the detail. Consequently, in the component system specified by this invention, when forming not only reduction and B addition of the simple amount of P but the relation of [%P] <=6x[%B]+0.005 between the amount of P, and the amount of B, it turned out that fatigue strength is improved further, without having an adverse effect on workability.

[0013] As an index of the general improvement in workability, it is mentioned that reinforcement, such as hardness and tensile strength, is low, that the elongation acquired by the usual tension test is large, etc. In addition to usual blanking nature and bending nature, for the application to which heat treatment by high density energy beam exposure is performed, local ductility, such as hole expansion property and fine-blanking nature, is needed in many cases. It turned out that local ductility has notch **** elongation and a strong correlation from the result of the examination and research by this invention person etc.

[0014] The quality of fine-blanking processing as which local ductility is required is judged with the generation difficulty of the fracture surface in a blanking side. It is thought that generation of the fracture surface is sensitively caused by the very local defect produced during processing deformation. In hole expansion property, local deformation (burring) is further added to the part which deformed locally by stamping. Therefore, hole expansion property and fine-blanking nature have the notch **** elongation (ElV value) which is the index of local ductility, and a strong correlation. In a carbon steel plate, it is mentioned to the cause of generation of a defect with local growth (connection) of the micro void produced with carbide (cementite) as the starting point. It is thought that adjustment of this point, the hole expansion property of a carbon steel plate, and the metal texture where generation and growth of a micro void will be controlled as

much as possible by improvement of notch **** elongation at the time of processing deformation if it puts in another way is important. It is imagined to be the cause that the micro defect to which it does not affect other workability that notch **** elongation is not necessarily similarly improved with an improvement of other general workability influences sensitively to notch **** elongation.

[0015] If it was in the steel plate with a ferrite + pearlite organization as a result of repeating various experiments based on such consideration, when making a ferrite and a pearlite detailed, connection of the micro void which generated the pearlite as an origin was controlled, and it checked that local ductility, i.e., notch **** elongation, such as hole expansion property and fine-blanking nature, was improved notably. In case the hot-rolled steel strip is rolled round for detailed-ization of a ferrite and a pearlite, low-temperature rolling up of 600 degrees C or less is preferably effective in it. Although lowering of the amount of C and the amount of Mn is advantageous to an improvement of notch **** elongation among the components of a steel plate, lowering of the amount of C and the amount of Mn is easy to degrade heat treatability, such as reservation of hardenability and hardening hardness. In order to control lowering of heat treatability and to improve notch **** elongation, the addition of Ti, B, Cr, etc. of optimum dose is effective. If the quality governing of Ti, B, the Cr, etc. is added and carried out, the heat treatability by high density energy beam exposure will also improve.

[0016] Hereafter, an alloy content, a content, etc. which are contained in this invention steel plate are explained.

C content is aimed at the medium carbon steel in the range which is 0.15 - 0.50 % of the weight for C:0.15 - 0.50-% of the weight this invention. C is a basic alloy content most in carbon steel, and hardening hardness, the amount of carbide, etc. are sharply changed according to C content. Notch **** elongation improves so that C content is low, but in order to secure sufficient hardening hardness, 0.15 % of the weight or more is required. However, if C of the excessive amount exceeding 0.50 % of the weight is contained, the manufacturability and the handling nature of a steel strip not only worsen, but the toughness after hot-rolling will fall and notch **** elongation sufficient after annealing will not be acquired. Therefore, C content was set to 0.15 - 0.50% of the weight of the range from from [when obtaining the steel plate which has the moderate hardening hardness and the workability by high density energy beam exposure].

[0017] Si: It is the alloy content which affects the notch **** elongation which is local ductile indexes, such as 0.30 or less % of the weight hole expansion property and fine-blanking nature, and Si of the excessive amount exceeding 0.30 % of the weight hardens a ferrite or bainite according to a solid-solution-strengthening operation, and causes crack generating at the time of a fabricating operation. Moreover, it becomes easy to generate a scale crack on a steel plate front face in a manufacture process with the increment in Si content, and the surface quality of a steel plate is reduced.

Mn: Raise the hardenability of a steel plate 0.3 to 1.0% of the weight, and it is an alloy content effective also in toughening. In order to acquire sufficient hardenability, 0.3% of the weight or more of Mn is required. However, if Mn of the excessive amount exceeding 1.0 % of the weight is contained, a ferrite or bainite will harden and workability will fall.

[0018] although it is the component which has an adverse effect on a fatigue property P:0.03 or less % of the weight, until allowance is carried out to some extent by balance adjustment with the amount of B. However, if P content exceeds 0.03 % of the weight, the inclination to degrade ductility and toughness will become large irrespective of balance adjustment with the amount of B.

It is the injurious ingredient which forms MnS system inclusion S:0.01 or less % of the weight. Since notch **** elongation will fall if MnS system inclusion increases in number, S content is so desirable that it is low as much as possible. However, if it adjusts to the organization of a ferrite + pearlite, there is no need for the formation of super-low S, and even if it is common commercial steel, fine-blanking nature and notch **** elongation will be improved. However, even if it is in the steel plate which raised C content to about 0.50 % of the weight, in order to be stabilized and to secure high notch **** elongation, the upper limit of S content is specified to 0.01% of the weight. Moreover, in order to be stabilized and to obtain a steel plate with the

dramatically excellent notch **** elongation, it is desirable to **** S content to 0.005 or less % of the weight.
[0019] Ti: It is the component used for deoxidation adjustment of molten steel 0.01 to 0.15% of the weight, and also present denitrification. Moreover, since N which is dissolving in steel is fixed as a nitride, the amount required for an improvement of hardenability of validity B is raised. Furthermore, carbon nitride effective in the coarsening prevention at the time of hardening is formed. In order to be stabilized and to acquire these operations, 0.01% of the weight or more of Ti is required. However, Ti of the excessive amount exceeding 0.15 % of the weight is not only economically disadvantageous, but becomes the cause of degrading local ductility, i.e., notch **** elongation.
It is an alloy content required in order to present the operation which raises heat treatability substantially by addition of ultralow volume B:0.0005 to 0.0050% of the weight, to be stabilized and to obtain hardening hardness. Although such an operation becomes remarkable with 0.0005% of the weight or more of B content, it is saturated with the 0.0050 % of the weight of the amounts of B, and even if it adds B exceeding 0.0050 % of the weight, toughness deteriorates on the contrary.
[0020] It is the alloy content which presents the operation which combines with Ti N:0.01 or less % of the weight, serves as TiN, and makes detailed crystal grain at the time of hardening. However, if N content exceeds 0.01 % of the weight, ductility will fall. Moreover, superfluous N combines with B and consumes the amount effective in an improvement of hardenability of B.
aluminum: 0.02 - 0.10-% of the weight aluminum is a component used as a deoxidizer of molten steel, and also present the operation which fixes N as AlN. Such an operation becomes remarkable with 0.02% of the weight or more of aluminum content. However, if the amount of aluminum in steel exceeds 0.10 % of the weight, the cleanliness of steel will become easy to generate a surface crack in a disadvantage crack and a steel plate.
Cr: It is the alloy content added if needed 0.5 or less % of the weight, and while improving hardenability, enlarge resistance to temper softening. However, addition of Cr of the excessive amount exceeding 0.5 % of the weight sees the inclination for notch **** elongation and general workability to fall.
[0021]
[Example 1] The steel of the presentation shown in a table 1 was ingoted. Steel A-D is steel with which are satisfied of the component conditions specified by this invention, and [%P] <=6x[%B]+0.005. Among comparison steel E-K, although Steel E satisfies [%P] <=6x[%B]+0.005, C content is lower than the range specified by this invention. It is not satisfied with the point that Steel F has high C content and Ti and B are not added of the conditions specified by this invention. Steel G is S35C of a JIS steel type, and is not satisfied with the point that Ti and B are not added of the conditions specified by this invention. Steel H is not satisfied with the point that there are many amounts of N and Ti and B are not added of the conditions specified by this invention. Steel I and J is steel with which are not satisfied of [%P] <=6x[%B]+0.005. It is not satisfied with the point that Steel K has high Cr content and Ti and B are not added of the conditions specified by this invention.
[0022]

表１：実施例１で使用した鋼材の種類

鋼種記号	合金成分及び含有量 (重量%)										X値	区分
	C	Si	Mn	P	S	Cr	Ti	B	Al	N		
A	0.35	0.05	0.31	0.012	0.005	0.28	0.03	0.0042	0.030	0.0027	0.030	本発明例
B	0.22	0.23	0.53	0.019	0.003	0.45	0.05	0.0049	0.022	0.0030	0.034	
C	0.45	0.02	0.36	0.010	0.007	0.13	0.03	0.0038	0.032	0.0025	0.028	
D	0.20	0.06	0.88	0.006	0.004	0.34	0.11	0.0008	0.027	0.0032	0.010	
E	0.10	0.19	0.43	0.011	0.006	—	0.02	0.0024	0.018	0.0030	0.019	比較例
F	0.65	0.25	1.23	0.010	0.005	—	—	—	0.026	0.0030	—	
G	0.34	0.21	0.69	0.012	0.008	—	—	—	0.023	0.0029	—	
H	0.45	0.24	0.55	0.025	0.012	—	—	—	0.033	0.0280	—	
I	0.34	0.05	0.28	0.028	0.005	0.31	0.02	0.0034	0.031	0.0033	0.025	
J	0.45	0.08	0.44	0.017	0.007	—	0.03	0.0007	0.024	0.0260	0.009	
K	0.35	0.06	0.40	0.013	0.006	0.82	—	—	0.032	0.0025	—	

X値＝６×Ｂ＋０．００５

[0023] The steel ingot which cast and obtained each molten steel was hot-rolled, and it considered as the hot-rolling plate of 4.0mm of board thickness. The hot-rolling organization was changed by changing coil rolling-up temperature at the time of hot-rolling. The front face of the test piece cut down from each steel plate was ground with the emery paper with which the yarn counts differ, and the sample which changed surface roughness was prepared. And after heat-treating under electron beam exposure conditions with a part [for the acceleration voltage of 60kV, the beam current of 70mA, the beam amplitude frequency of 1.5kHz, and exposure speed 4m/], and an exposure width of face of 10mm, visual observation of the crater-like surface discontinuity generated in the heat treatment section was carried out, and it asked for the crater-like surface-discontinuity generating number per unit area (/cm2).

[0024] At the test numbers 1-8 (example of this invention) which adjusted surface roughness to 0.2-4.8 micrometers of Ra as seen in the table 2 showing the relation between the surface roughness of a raw material steel plate, and the crater-like defective generating number, the crater-like surface-discontinuity generating number of the heat treatment section is 2 0-2 pieces/cm. It has become and the good front face was presented. On the other hand, at the test numbers 9-14 (example of a comparison) to which surface roughness was coarsely adjusted with 5.6-14.7 micrometers of Ra, the crater-like surface-discontinuity generating number of the heat treatment section is 2 9-19 pieces/cm. As compared with the example of this invention, remarkably, and it had become surface [poor].

[0025]

表２：素材鋼板の表面粗さがクレータ状表面欠陥に及ぼす影響

試験番号	鋼種記号	表面粗さRa μm	クレータ状表面欠陥の発生個数 個／cm²	区分
1	A	3.8	1	本発明例
2	A	0.2	0	
3	B	4.8	2	
4	B	2.3	0	
5	C	4.4	2	
6	C	2.8	1	
7	D	1.4	0	
8	D	3.0	1	
9	A	6.9	10	比較例
10	A	9.8	15	
11	B	5.6	10	
12	C	6.8	9	
13	C	14.7	19	
14	D	5.9	9	

[0026] Furthermore, the test piece was heat-treated for the test piece cut down from each steel plate by the electron beam exposure with a part [for the acceleration voltage of 60kV, the beam current of 70mA, the beam amplitude frequency of 1.5kHz, and exposure speed 4m/], and an exposure width of face of 10mm, and the cross section hardness of the heat treatment section was measured. And the distance to the location blank test piece front face where the hardness equivalent to 80% of maximum hardness is obtained was measured, and it considered as the depth of a hardening layer. Moreover, after carrying out the electron beam exposure of front flesh-side both sides of a test piece on conditions with a part [for the acceleration voltage of 60kV, the beam current of 70mA, the beam amplitude frequency of 1.5kHz and exposure speed 4m/], and an exposure width of face of 30mm, the fatigue limit was measured by both the swing fatigue test (frequency of 23Hz) of plane bending.

[0027] As compared with the test number 27 (the example of a comparison, steel G) of the almost same C content, the hardening layer was as deep as about 350 micrometers, and the fatigue property was also excellent in test numbers 15 and 16 (example of this invention) so that the results of an investigation of a table 3 might see. Although test numbers 17, 18, 21, and 22 (example of this invention) have C content as low as about 0.2 % of the weight as compared with 0.34 % of the weight of C contents of a test number 27 (the example of a comparison, steel G), the deep hardening layer is formed. Test numbers 19 and 20 (example of this invention) had the deep hardening layer as compared with the test number 28 (the example of a comparison, steel H) of the almost same C content, and the fatigue property was also excellent.

[0028] test numbers 29 and 30 (example of a comparison) any -- [%P] <=6x [%B] the conditions of +0.005 are satisfied -- not having -- the test numbers 15 and 16 (example of this invention) with respectively almost same C content And test numbers 19 and 20 (example of this invention) The fatigue limit is low although it has the hardening layer depth of the same level. Although test numbers 23-25 (example of a comparison) make steel A-C a balling-up carbide organization, respectively, as compared with the test numbers 15-20 (example of this invention) with a ferrite + pearlite organization, a hardening layer is shallow and the fatigue limit is also low. In the test number 26, since there were few C contents than the minimum specified by this invention, the hardening layer was also shallow low, and maximum hardness is on a actual activity and caused

trouble.
[0029]

表３：各鋼板の熱処理性及び熱処理後の疲労特性

試験番号	鋼種記号	熱処理で形成された硬化層		熱処理後の疲労限度	区分
		最高硬さ, HV0.1	深さ, μm	N/mm²	
15	A	623	344	270	本発明例
16	A	627	351	275	
17	B	523	320	260	
18	B	530	318	255	
19	C	683	360	295	
20	C	681	367	285	
21	D	523	315	255	
22	D	528	310	255	
23	A	620	243	220	比較例
24	B	532	224	205	
25	C	675	264	235	
26	E	340	110	—	
27	G	613	286	225	
28	H	691	321	210	
29	I	625	347	195	
30	J	681	362	195	

[0030] Furthermore, various rolling-up temperature after hot-rolling was changed, and the effect to which rolling-up temperature does to the notch **** elongation of a steel plate was investigated. By the notch tension test, it is JIS. The tensile test was carried out to the crosswise both sides in the parallel part longitudinal direction mid gear of a No. 5 test piece using the test piece in which 45 aperture angles and a V notch with a depth of 2mm were formed. And ElV which asked for the elongation percentage to 5mm of gauge length containing a V notch after fracture of a test piece, and was obtained The value estimated workability. Results of an investigation are shown in a table 4. Test numbers 31-38 (example of this invention) are high ElV as compared with the test numbers 39 and 40 (example of this invention) to which steel A-D is rolled round, and it hot-rolls at the temperature of 600 degrees C or less, and rolls round by the same steel type, and temperature exceeds 600 degrees C. The value is shown and it turns out that it excels in local ductility. On the other hand, it is ElV even if it rolls round so that test numbers 43 and 44 (example of a comparison) may see, when the steel G and H with which are not satisfied of the component conditions specified by this invention is used, and temperature is 600 degrees C or less. The value is low. Moreover, at the test numbers 45 and 46 (example of a comparison) rolled round at the temperature which exceeds 600 degrees C, using the steel F and K with many C contents and Cr contents, it is ElV. The value was as low as 22% and 27%, and inferior to workability.
[0031]

表４：熱延巻取り温度が切欠き引張伸びに及ぼす影響

試験番号	鋼種記号	熱延巻取温度 ℃	切欠引張伸び El_v値 %	区分
31	A	580	38	本発明例
32	A	560	40	
33	B	580	41	
34	B	480	43	
35	C	580	35	
36	C	530	38	
37	D	580	40	
38	D	500	42	
39	A	630	34	
40	B	650	34	
41	C	680	29	
42	D	650	33	
43	G	580	34	比較例
44	H	580	29	
45	F	680	22	
46	K	650	27	

[0032]
[Example 2] The steel of the presentation shown in a table 5 was ingoted. Steel L-O is steel with which are satisfied of the component conditions specified by this invention, and [%P] <=6x[%B]+0.005. Among comparison steel P-U, although Steel P satisfies [%P] <=6x[%B]+0.005, C content is lower than the range specified by this invention. It is not satisfied with the point that Steel Q has high C content and Ti and B are not added of the conditions specified by this invention. Steel R is S35C of a JIS steel type, and is not satisfied with the point that Ti and B are not added of the conditions specified by this invention. Steel S is not satisfied with the point that there are many amounts of N and Ti and B are not added of the conditions specified by this invention. Steel T and U is steel with which are not satisfied of [%P] <=6x[%B]+0.005.
[0033]

表５：実施例２で使用した鋼材の種類

鋼種記号	合金成分及び含有量 (重量%)										X値	区分
	C	Si	Mn	P	S	Cr	Ti	B	Al	N		
L	0.36	0.04	0.33	0.011	0.005	0.29	0.02	0.0045	0.030	0.0035	0.032	本発明例
M	0.23	0.25	0.50	0.020	0.003	0.42	0.05	0.0033	0.022	0.0033	0.025	本発明例
N	0.48	0.01	0.34	0.009	0.008	0.11	0.03	0.0040	0.038	0.0024	0.029	本発明例
O	0.20	0.06	0.88	0.006	0.004	0.47	0.11	0.0008	0.027	0.0032	0.010	本発明例
P	0.12	0.33	0.52	0.011	0.006	—	0.05	0.0031	0.020	0.0034	0.024	比較例
Q	0.65	0.25	1.23	0.010	0.005	—	—	—	0.024	0.0030	—	比較例
R	0.35	0.23	0.71	0.013	0.009	—	—	—	0.021	0.0033	—	比較例
S	0.45	0.24	0.55	0.025	0.012	—	—	—	0.033	0.0280	—	比較例
T	0.35	0.06	0.31	0.035	0.006	0.35	0.03	0.0036	0.030	0.0025	0.027	比較例
U	0.45	0.08	0.44	0.017	0.007	—	0.03	0.0007	0.024	0.0260	0.009	比較例

X値＝６×Ｂ＋０．００５

[0034] The steel ingot which cast and obtained each molten steel was hot-rolled, and it considered as the hot-rolling plate of 4.0mm of board thickness. After holding a hot-rolling plate at 900 degrees C for soak 15 minutes, it held at 300-500 degrees C for 30 minutes, and was made the bainite texture. About a part of steel L-N, annealing of soak 20 hours was given at 700 more degrees C, and it was made the balling-up carbide organization. The front face of the test piece cut down from each steel plate was ground with the emery paper with which the yarn counts differ, and the sample which changed surface roughness was prepared. And after heat-treating under electron beam exposure conditions with a part [for the acceleration voltage of 60kV, the beam current of 70mA, the beam amplitude frequency of 1.5kHz, and exposure speed 4m/], and an exposure width of face of 10mm, visual observation of the crater-like surface discontinuity generated in the heat treatment section was carried out, and it asked for the crater-like surface-discontinuity generating number per unit area (/cm2).

[0035] At the test numbers 51-58 (example of this invention) which adjusted surface roughness to 0.5-4.7 micrometers of Ra as seen in the table 6 showing the relation between the surface roughness of a raw material steel plate, and the crater-like defective generating number, the crater-like surface-discontinuity generating number of the heat treatment section is 2 0-2 pieces/cm. It has become and the good front face was presented. On the other hand, at the test numbers 59-64 (example of a comparison) to which surface roughness was coarsely adjusted with 5.7-13.5 micrometers of Ra, the crater-like surface-discontinuity generating number of the heat treatment section is 2 9-17 pieces/cm. As compared with the example of this invention, remarkably, and it had become surface [poor].

[0036]

* 表6：素材鋼板の表面粗さがクレータ状表面欠陥に及ぼす影響

試験番号	鋼種記号	表面粗さRa μm	クレータ状表面欠陥の発生個数 個／cm^2	区分
51	L	4.0	2	本発明例
52	L	0.5	0	
53	M	3.3	1	
54	M	2.1	0	
55	N	4.7	2	
56	N	3.6	2	
57	O	1.4	0	
58	O	2.5	0	
59	L	6.0	10	比較例
60	L	9.4	15	
61	M	5.7	9	
62	N	7.8	11	
63	N	13.5	17	
64	O	7.3	9	

[0037] Furthermore, the test piece was heat-treated for the test piece cut down from each steel plate by the electron beam exposure with a part [for the acceleration voltage of 60kV, the beam current of 70mA, the beam amplitude frequency of 1.5kHz, and exposure speed 4m/], and an exposure width of face of 10mm, and the cross section hardness of the heat treatment section was measured. And the distance to the location blank test piece front face where the hardness equivalent to 80% of maximum hardness is obtained was measured, and it considered as the depth of a hardening layer. Moreover, after carrying out the electron beam exposure of front flesh-side both sides of a test piece on conditions with a part [for the acceleration voltage of 60kV, the beam current of 70mA, the beam amplitude frequency of 1.5kHz and exposure speed 4m/], and an exposure width of face of 30mm, the fatigue limit was measured by the same fatigue test as an example 1.
[0038] As compared with the test number 77 (the example of a comparison, steel R) of the almost same C content, the hardening layer was as deep as about 340 micrometers, and the fatigue property was also excellent in test numbers 65 and 66 (example of this invention) so that the results of an investigation of a table 7 might see. Although test numbers 67, 68, 71, and 72 (example of this invention) have C content as low as about 0.2 % of the weight as compared with 0.35 % of the weight of C contents of a test number 77 (the example of a comparison, steel R), the deep hardening layer is formed. Although C content of maximum hardness was almost equivalent at the test numbers 65-70 made into the bainite texture although test numbers 73-75 (example of a comparison) made steel L-N the balling-up carbide organization, respectively as compared with the thing of this level, raw material reinforcement was low, and since the hardening layer was shallow, moreover, fatigue strength was falling. Test numbers 69 and 70 (example of this invention) had the hardening layer as deep as 360 micrometers as compared with the test number 78 (the example of a comparison, steel S) of the almost same C content, and since there was also little crater-like surface discontinuity, the remarkably excellent fatigue property was shown. test numbers 79 and 80 (example of a comparison) any — [%P] <=6x [%B] the conditions of +0.005 are satisfied — not having — the test numbers 65 and 66 (example of this invention) with respectively almost same C content And test numbers 69 and 70 (example of

this invention) The fatigue limit is low although it has the hardening layer depth of the same level. In the test number 76 (example of a comparison), since there were few C contents than the minimum specified by this invention, the hardening layer was also shallow low, and maximum hardness is on a actual activity and caused trouble.

[0039]

表７：各鋼板の熱処理性及び熱処理後の疲労特性

試験番号	鋼種記号	熱処理で形成された硬化層		熱処理部の疲労限度	区分
		最高硬さ, HV0.1	深さ, μm	N/mm²	
65	L	624	340	355	本発明例
66	L	617	338	350	
67	M	522	318	285	
68	M	529	316	275	
69	N	671	364	420	
70	N	679	373	430	
71	O	520	329	290	
72	O	518	318	280	
73	L	617	250	220	比較例
74	M	532	239	205	
75	N	668	264	240	
76	P	346	115	—	
77	R	631	277	240	
78	S	682	301	217	
79	T	620	336	230	
80	U	679	365	235	

[0040]

[Effect of the Invention] As explained above, the low-alloy-steel steel plate of this invention maintains the front face of the heat treatment section in which the alloy content was adjusted, it considered as the ferrite + pearlite mixing organization, the ferrite + bainite mixing organization, or the bainite texture, the deep hardening layer was formed in by heat treatment by high density energy beam exposure, and the hardening layer was moreover formed good, and is raising the fatigue property after heat treatment. Thus, the low-alloy-steel steel plate of this invention is conjointly used as parts for various machines including the components for automobile loading with excelling in workability.

[Translation done.]

TECHNICAL FIELD

[Industrial Application] After this invention irradiates high density energy beams, such as an electron beam, and heats the steel plate surface section, it is suitable for rapid heat treatment which forms a hardening layer in a surface by carrying out self-cooling, and it relates to the low-alloy-steel steel plate excellent in the fatigue property after heat treatment.

[Translation done.]

PRIOR ART

[Description of the Prior Art] It was common to perform hardening processing of carburization, nitriding, etc. to plain steel in the machine part for automobile loading, in order to secure reinforcement, a fatigue property, and abrasion resistance, or to have used special steel, carrying out hardening annealing. In recent years, in order to plan cost reduction, the approach of carrying out local heat treatment only of the part where reinforcement, a fatigue property, toughness, abrasion resistance, etc. are demanded is adopted. As local heat treatment, the approach of carrying out high frequency induction heating of the need part, the method of irradiating a high density energy beam and heating it, etc. are adopted. Especially the heat-treating method using a high density energy beam has the advantage which can heat-treat only the necessary minimum part of components with a complicated configuration.
[0003] In heat treatment using a high density energy beam, while optimizing the workability and reinforcement of a raw material according to the components and part to apply, it is required that the fatigue property according to desired reinforcement and a desired application, abrasion resistance, etc. should be given to the heat treatment section by which the high density energy beam exposure was carried out. About the workability of a raw material, even if it is a hard bainite texture and the low pearlite organization of deformability as compared with the organization where carbon steel with a difficulty also has a spheroidal carbide in workability with an advance of a processing technique depending on a processing gestalt conventionally, it is becoming processible.
[0004] However, the workability of a steel plate with a pearlite organization is still low, and although workability like a steel plate with a balling-up carbide organization is not needed, it is required that workability should be improved as much as possible. Furthermore, it is necessary to raise material properties, such as heat treatability using a high density energy beam, and a fatigue property after heat treatment. Moreover, to use special steel for the severe application of processing, while raising workability by considering as a balling-up carbide organization and it is required to raise the heat treatability using a high density energy beam exposure, in the case of bending, slight spinning, bulging, burring, etc., importance is not attached so much to workability, but improvement in the heat treatability by the high density energy beam, improvement in the fatigue property after heat treatment, etc. are required rather. Furthermore, since the heat treatment section heated by the high density energy beam exposure is high-intensity-ized, it is necessary to change a front face into a smooth condition as much as possible from a fatigue property or a wear-resistant viewpoint.
[0005] The approach of forming a hardening layer in a steel plate front face by high density energy beam exposure is introduced to JP,10-121125,A. By this approach, using an electron beam as a high density energy beam, if it puts in another way in the depth of melting and the coagulation section at the time of heat treatment, and a heat affected zone, the depth of a hardening layer will be secured. An object steel type is a comparatively general steel type called tool steel, such as alloy steel, such as carbon steel, such as S50C and S10C, SNCM, and SCR, SCM, and SK, SKS, and is not a steel type in consideration of the heat treatability by high density energy beam exposure, or the workability and the moldability before heat treatment. Moreover, by optimizing the output of a high density energy beam, and irradiation time according

to the width of face of the fusion zone by high density energy beam exposure, and working speed, flapping on the front face of a steel plate is controlled, and maintaining the surface state of the surface treatment section influenced by the melting depth good is also indicated. However, in heat treatment using a high density energy beam, it lenticulated from the result of the examination and research by this invention person etc., crater-like surface discontinuity arose also in except, and it became clear to degrade the engine performance.
[0006] The method of performing heat treatment penetrated in the direction of board thickness is also learned, using a laser beam as a high density energy beam (JP,6-73438,A, JP,6-73439,A, JP,6-73440,A, JP,6-73441,A, JP,6-73442,A, JP,6-73443,A). For example, in JP,6-73440,A, the steel plate in which heat treatment by laser beam exposure is possible is introduced, maintaining the balance of workability and the amount of on-the-strength lifting according to a convention of an alloy content about a steel plate with a pearlite or a cementite, and a ferrite. Moreover, in JP,6-73438,A, the heat treatability by the laser beam exposure aiming at the balance of workability and the amount of on-the-strength lifting is improved by adjusting the alloy content of a steel plate with bainite and a ferrite. However, although the surface state of neither after a laser beam exposure is also clear and reinforcement is taken up about the material property after a laser beam exposure, it is not indicated about a fatigue property.

[Translation done.]

EFFECT OF THE INVENTION

[Effect of the Invention] As explained above, the low-alloy-steel steel plate of this invention maintains the front face of the heat treatment section in which the alloy content was adjusted, it considered as the ferrite + pearlite mixing organization, the ferrite + bainite mixing organization, or the bainite texture, the deep hardening layer was formed in by heat treatment by high density energy beam exposure, and the hardening layer was moreover formed good, and is raising the fatigue property after heat treatment. Thus, the low-alloy-steel steel plate of this invention is conjointly used as parts for various machines including the components for automobile loading with excelling in workability.

[Translation done.]

TECHNICAL PROBLEM

[Problem(s) to be Solved by the Invention] Thus, in heat treatment using the high density energy beam exposure currently indicated conventionally, the depth (depth of a hardening layer) of melting, the coagulation section, and a heat affected zone is enlarged more, and the surface treatment section influenced by the melting depth is maintained at a good surface state, and it is not clarified enough about the steel plate which was further excellent in the fatigue property after heat treatment. Then, this invention enlarges more the depth of the hardening layer produced by the exposure of a high density energy beam, maintains the surface state of the surface treatment section influenced by the melting depth good, and aims at offering the steel plate which was further excellent in the fatigue property after heat treatment.

[Translation done.]

MEANS

[Means for Solving the Problem] In order that the low-alloy-steel steel plate of this invention may attain the object, C: 0.15 - 0.50 % of the weight, Si: 0.30 or less % of the weight, Mn: 0.3 - 1.0 % of the weight, P:0.03 % of the weight or less, S:0.01 % of the weight or less, Ti:0.01-0.15 % of the weight, B:0.0005 - 0.0050 % of the weight, N:0.01 % of the weight or less, aluminum:0.02-0.10 % of the weight, and Cr:0-0.5 % of the weight are included. The remainder has substantially the presentation which is satisfied with Fe of [%P] <=6x[%B]+0.005, a mixed organization or a bainite texture with a ferrite, a pearlite, or bainite is presented, and it is characterized by adjusting surface roughness to Ra<=5micrometer.

[Translation done.]

OPERATION

[Function] this invention person etc. investigated and studied many things about the conditions from which the low alloy steel which was excellent in workability and was excellent in the heat treatability by high density energy beam exposure and the fatigue property after heat treatment is obtained. It is estimated that what has the deeper hardening layer in the direction of board thickness formed by heat treatment is better as for the heat treatability by high density energy beam exposure. If a hardening layer is deep, abrasion resistance and endurance improve, and since surface compressive residual stress can be enlarged, fatigue strength will also improve. Then, this invention person etc. heat-treated the steel plate which has various presentations, using an electron beam as a high density energy beam, and investigated the effect an alloy presentation affects heat treatability. Consequently, to common carbon steel and steel for machine structural use, it solved it was effective to make it a ferrite + pearlite organization, a ferrite + bainite texture, or a bainite texture rather than having considered a raw material as a balling-up carbide organization.
[0010] If the steel plate of a ferrite + pearlite organization, a ferrite + bainite texture, or a bainite texture is heat-treated by high density energy beam exposure, when heated more than the alpha->gamma transformation point, since a pearlite and bainite are quicker than a spheroidal carbide, as for the rate which dissolves in gamma, a hardening layer will become deeper. Moreover, in a steel plate with a ferrite + pearlite organization, a ferrite + bainite texture, or a bainite texture, if C, Si, Mn, and the amount of Cr(s) are adjusted so that workability may not be degraded, and hardenability is further raised by B addition of optimum dose, a still deeper hardening layer will be formed.
[0011] The shape of table planarity of a hardening layer is influenced by the surface roughness of a raw material steel plate. If the surface roughness before heat treatment is large, it will become easy to generate crater-like surface discontinuity on the heat-treated steel plate front face. In case the bottom of the crevice in a steel plate front face fuses generating of crater-like surface discontinuity by high density energy beam exposure, it is guessed that a cause is to involve in the gas generated from the fats and oils which remained at atmospheric air or a bottom, dirt, etc. Crater-like surface discontinuity presents the notch effect which degrades a fatigue property while having an adverse effect on abrasion resistance. The research result by this invention person etc. showed not generating on the steel plate front face after the crater-like surface discontinuity which has an adverse effect on abrasion resistance or a fatigue property heat-treating, when setting surface roughness of a raw material steel plate to Ra<=5micrometer.
[0012] Adjustment of P and B can be considered as a general policy which improves a fatigue property of a minute amount addition component. That is, the amount of P which it segregates [amount] to a grain boundary and promotes embrittlement is reduced, and if B which segregates to a grain boundary and strengthens a grain boundary is added, a fatigue property will improve. Reduction and B addition of the amount of P do not have an adverse effect on the workability of the steel plate before heat treatment, either. However, reduction of the amount of P becomes disadvantageous economically in a steel-manufacture phase. Then, the steel plate to which various the amounts of P and the amounts of B were changed was heat-treated by the

electron beam exposure, the fatigue test of a bending type was presented, and the balance of the amount effective in a fatigue limit improvement of P and the amount of B was investigated in the detail. Consequently, in the component system specified by this invention, when forming not only reduction and B addition of the simple amount of P but the relation of [%P] <=6x[%B]+0.005 between the amount of P, and the amount of B, it turned out that fatigue strength is improved further, without having an adverse effect on workability.
[0013] As an index of the general improvement in workability, it is mentioned that reinforcement, such as hardness and tensile strength, is low, that the elongation acquired by the usual tension test is large, etc. In addition to usual blanking nature and bending nature, for the application to which heat treatment by high density energy beam exposure is performed, local ductility, such as hole expansion property and fine-blanking nature, is needed in many cases. It turned out that local ductility has notch **** elongation and a strong correlation from the result of the examination and research by this invention person etc.
[0014] The quality of fine-blanking processing as which local ductility is required is judged with the generation difficulty of the fracture surface in a blanking side. It is thought that generation of the fracture surface is sensitively caused by the very local defect produced during processing deformation. In hole expansion property, local deformation (burring) is further added to the part which deformed locally by stamping. Therefore, hole expansion property and fine-blanking nature have the notch **** elongation (ElV value) which is the index of local ductility, and a strong correlation. In a carbon steel plate, it is mentioned to the cause of generation of a defect with local growth (connection) of the micro void produced with carbide (cementite) as the starting point. It is thought that adjustment of this point, the hole expansion property of a carbon steel plate, and the metal texture where generation and growth of a micro void will be controlled as much as possible by improvement of notch **** elongation at the time of processing deformation if it puts in another way is important. It is imagined to be the cause that the micro defect to which it does not affect other workability that notch **** elongation is not necessarily similarly improved with an improvement of other general workability influences sensitively to notch **** elongation.
[0015] If it was in the steel plate with a ferrite + pearlite organization as a result of repeating various experiments based on such consideration, when making a ferrite and a pearlite detailed, connection of the micro void which generated the pearlite as an origin was controlled, and it checked that local ductility, i.e., notch **** elongation, such as hole expansion property and fine-blanking nature, was improved notably. In case the hot-rolled steel strip is rolled round for detailed-ization of a ferrite and a pearlite, low-temperature rolling up of 600 degrees C or less is preferably effective in it. Although lowering of the amount of C and the amount of Mn is advantageous to an improvement of notch **** elongation among the components of a steel plate, lowering of the amount of C and the amount of Mn is easy to degrade heat treatability, such as reservation of hardenability and hardening hardness. In order to control lowering of heat treatability and to improve notch **** elongation, the addition of Ti, B, Cr, etc. of optimum dose is effective. If the quality governing of Ti, B, the Cr, etc. is added and carried out, the heat treatability by high density energy beam exposure will also improve.
[0016] Hereafter, an alloy content, a content, etc. which are contained in this invention steel plate are explained.
C content is aimed at the medium carbon steel in the range which is 0.15 - 0.50 % of the weight for C:0.15 - 0.50-% of the weight this invention. C is a basic alloy content most in carbon steel, and hardening hardness, the amount of carbide, etc. are sharply changed according to C content. Notch **** elongation improves so that C content is low, but in order to secure sufficient hardening hardness, 0.15 % of the weight or more is required. However, if C of the excessive amount exceeding 0.50 % of the weight is contained, the manufacturability and the handling nature of a steel strip not only worsen, but the toughness after hot-rolling will fall and notch **** elongation sufficient after annealing will not be acquired. Therefore, C content was set to 0.15 - 0.50% of the weight of the range from from [when obtaining the steel plate which has the moderate hardening hardness and the workability by high density energy beam exposure].
[0017] Si: It is the alloy content which affects the notch **** elongation which is local ductile

indexes, such as 0.30 or less % of the weight hole expansion property and fine-blanking nature, and Si of the excessive amount exceeding 0.30 % of the weight hardens a ferrite or bainite according to a solid-solution-strengthening operation, and causes crack generating at the time of a fabricating operation. Moreover, it becomes easy to generate a scale crack on a steel plate front face in a manufacture process with the increment in Si content, and the surface quality of a steel plate is reduced.
Mn: Raise the hardenability of a steel plate 0.3 to 1.0% of the weight, and it is an alloy content effective also in toughening. In order to acquire sufficient hardenability, 0.3% of the weight or more of Mn is required. However, if Mn of the excessive amount exceeding 1.0 % of the weight is contained, a ferrite or bainite will harden and workability will fall.
[0018] although it is the component which has an adverse effect on a fatigue property P:0.03 or less % of the weight, until allowance is carried out to some extent by balance adjustment with the amount of B. However, if P content exceeds 0.03 % of the weight, the inclination to degrade ductility and toughness will become large irrespective of balance adjustment with the amount of B.
It is the injurious ingredient which forms MnS system inclusion S:0.01 or less % of the weight. Since notch **** elongation will fall if MnS system inclusion increases in number, S content is so desirable that it is low as much as possible. However, if it adjusts to the organization of a ferrite + pearlite, there is no need for the formation of super-low S, and even if it is common commercial steel, fine-blanking nature and notch **** elongation will be improved. However, even if it is in the steel plate which raised C content to about 0.50 % of the weight, in order to be stabilized and to secure high notch **** elongation, the upper limit of S content is specified to 0.01% of the weight. Moreover, in order to be stabilized and to obtain a steel plate with the dramatically excellent notch **** elongation, it is desirable to **** S content to 0.005 or less % of the weight.
[0019] Ti: It is the component used for deoxidation adjustment of molten steel 0.01 to 0.15% of the weight, and also present denitrification. Moreover, since N which is dissolving in steel is fixed as a nitride, the amount required for an improvement of hardenability of validity B is raised. Furthermore, carbon nitride effective in the coarsening prevention at the time of hardening is formed. In order to be stabilized and to acquire these operations, 0.01% of the weight or more of Ti is required. However, Ti of the excessive amount exceeding 0.15 % of the weight is not only economically disadvantageous, but becomes the cause of degrading local ductility, i.e., notch **** elongation.
It is an alloy content required in order to present the operation which raises heat treatability substantially by addition of ultralow volume B:0.0005 to 0.0050% of the weight, to be stabilized and to obtain hardening hardness. Although such an operation becomes remarkable with 0.0005% of the weight or more of B content, it is saturated with the 0.0050 % of the weight of the amounts of B, and even if it adds B exceeding 0.0050 % of the weight, toughness deteriorates on the contrary.
[0020] It is the alloy content which presents the operation which combines with Ti N:0.01 or less % of the weight, serves as TiN, and makes detailed crystal grain at the time of hardening. However, if N content exceeds 0.01 % of the weight, ductility will fall. Moreover, superfluous N combines with B and consumes the amount effective in an improvement of hardenability of B.
aluminum: 0.02 - 0.10-% of the weight aluminum is a component used as a deoxidizer of molten steel, and also present the operation which fixes N as AlN. Such an operation becomes remarkable with 0.02% of the weight or more of aluminum content. However, if the amount of aluminum in steel exceeds 0.10 % of the weight, the cleanliness of steel will become easy to generate a surface crack in a disadvantage crack and a steel plate.
Cr: It is the alloy content added if needed 0.5 or less % of the weight, and while improving hardenability, enlarge resistance to temper softening. However, addition of Cr of the excessive amount exceeding 0.5 % of the weight sees the inclination for notch **** elongation and general workability to fall.
[0021]
[Example 1] The steel of the presentation shown in a table 1 was ingoted. Steel A-D is steel

with which are satisfied of the component conditions specified by this invention, and [%P] <=6x[%B]+0.005. Among comparison steel E-K, although Steel E satisfies [%P] <=6x[%B]+0.005, C content is lower than the range specified by this invention. It is not satisfied with the point that Steel F has high C content and Ti and B are not added of the conditions specified by this invention. Steel G is S35C of a JIS steel type, and is not satisfied with the point that Ti and B are not added of the conditions specified by this invention. Steel H is not satisfied with the point that there are many amounts of N and Ti and B are not added of the conditions specified by this invention. Steel I and J is steel with which are not satisfied of [%P] <=6x[%B]+0.005. It is not satisfied with the point that Steel K has high Cr content and Ti and B are not added of the conditions specified by this invention.
[0022]

表１：実施例１で使用した鋼材の種類

鋼種記号	合金成分及び含有量 (重量%)										X値	区分
	C	Si	Mn	P	S	Cr	Ti	B	Al	N		
A	0.35	0.05	0.31	0.012	0.005	0.28	0.03	0.0042	0.030	0.0027	0.030	本発明例
B	0.22	0.23	0.53	0.019	0.003	0.45	0.05	0.0049	0.022	0.0030	0.034	
C	0.45	0.02	0.36	0.010	0.007	0.13	0.03	0.0038	0.032	0.0025	0.028	
D	0.20	0.06	0.88	0.006	0.004	0.34	0.11	0.0008	0.027	0.0032	0.010	
E	0.10	0.19	0.43	0.011	0.006	—	0.02	0.0024	0.018	0.0030	0.019	比較例
F	0.65	0.25	1.23	0.010	0.005	—	—	—	0.026	0.0030	—	
G	0.34	0.21	0.69	0.012	0.008	—	—	—	0.023	0.0029	—	
H	0.45	0.24	0.55	0.025	0.012	—	—	—	0.033	0.0280	—	
I	0.34	0.05	0.28	0.028	0.005	0.31	0.02	0.0034	0.031	0.0033	0.025	
J	0.45	0.08	0.44	0.017	0.007	—	0.03	0.0007	0.024	0.0260	0.009	
K	0.35	0.06	0.40	0.013	0.006	0.82	—	—	0.032	0.0025	—	

X値＝６×Ｂ＋０．００５

[0023] The steel ingot which cast and obtained each molten steel was hot-rolled, and it considered as the hot-rolling plate of 4.0mm of board thickness. The hot-rolling organization was changed by changing coil rolling-up temperature at the time of hot-rolling. The front face of the test piece cut down from each steel plate was ground with the emery paper with which the yarn counts differ, and the sample which changed surface roughness was prepared. And after heat-treating under electron beam exposure conditions with a part [for the acceleration voltage of 60kV, the beam current of 70mA, the beam amplitude frequency of 1.5kHz, and exposure speed 4m/], and an exposure width of face of 10mm, visual observation of the crater-like surface discontinuity generated in the heat treatment section was carried out, and it asked for the crater-like surface-discontinuity generating number per unit area (/cm2).
[0024] At the test numbers 1-8 (example of this invention) which adjusted surface roughness to 0.2-4.8 micrometers of Ra as seen in the table 2 showing the relation between the surface roughness of a raw material steel plate, and the crater-like defective generating number, the crater-like surface-discontinuity generating number of the heat treatment section is 2 0-2 pieces/cm. It has become and the good front face was presented. On the other hand, at the test numbers 9-14 (example of a comparison) to which surface roughness was coarsely adjusted with 5.6-14.7 micrometers of Ra, the crater-like surface-discontinuity generating number of the heat treatment section is 2 9-19 pieces/cm. As compared with the example of this invention, remarkably, and it had become surface [poor].

[0025]
表２：素材鋼板の表面粗さがクレータ状表面欠陥に及ぼす影響

試験番号	鋼種記号	表面粗さＲａ μｍ	クレータ状表面欠陥の発生個数 個／ｃｍ^2	区分
1	A	3.8	1	本発明例
2	A	0.2	0	
3	B	4.8	2	
4	B	2.3	0	
5	C	4.4	2	
6	C	2.8	1	
7	D	1.4	0	
8	D	3.0	1	
9	A	6.9	10	比較例
10	A	9.8	15	
11	B	5.6	10	
12	C	6.8	9	
13	C	14.7	19	
14	D	5.9	9	

[0026] Furthermore, the test piece was heat-treated for the test piece cut down from each steel plate by the electron beam exposure with a part [for the acceleration voltage of 60kV, the beam current of 70mA, the beam amplitude frequency of 1.5kHz, and exposure speed 4m/], and an exposure width of face of 10mm, and the cross section hardness of the heat treatment section was measured. And the distance to the location blank test piece front face where the hardness equivalent to 80% of maximum hardness is obtained was measured, and it considered as the depth of a hardening layer. Moreover, after carrying out the electron beam exposure of front flesh-side both sides of a test piece on conditions with a part [for the acceleration voltage of 60kV, the beam current of 70mA, the beam amplitude frequency of 1.5kHz and exposure speed 4m/], and an exposure width of face of 30mm, the fatigue limit was measured by both the swing fatigue test (frequency of 23Hz) of plane bending.
[0027] As compared with the test number 27 (the example of a comparison, steel G) of the almost same C content, the hardening layer was as deep as about 350 micrometers, and the fatigue property was also excellent in test numbers 15 and 16 (example of this invention) so that the results of an investigation of a table 3 might see. Although test numbers 17, 18, 21, and 22 (example of this invention) have C content as low as about 0.2 % of the weight as compared with 0.34 % of the weight of C contents of a test number 27 (the example of a comparison, steel G), the deep hardening layer is formed. Test numbers 19 and 20 (example of this invention) had the deep hardening layer as compared with the test number 28 (the example of a comparison, steel H) of the almost same C content, and the fatigue property was also excellent.
[0028] test numbers 29 and 30 (example of a comparison) any -- [%P] <=6x [%B] the conditions of +0.005 are satisfied -- not having -- the test numbers 15 and 16 (example of this invention) with respectively almost same C content And test numbers 19 and 20 (example of this invention) The fatigue limit is low although it has the hardening layer depth of the same level. Although test numbers 23-25 (example of a comparison) make steel A-C a balling-up carbide organization, respectively, as compared with the test numbers 15-20 (example of this invention) with a ferrite + pearlite organization, a hardening layer is shallow and the fatigue limit is also low. In the test number 26, since there were few C contents than the minimum specified by this invention, the

hardening layer was also shallow low, and maximum hardness is on a actual activity and caused trouble.
[0029]
表３：各鋼板の熱処理性及び熱処理後の疲労特性

試験番号	鋼種記号	熱処理で形成された硬化層		熱処理後の疲労限度	区分
		最高硬さ、 HV0.1	深さ、 μm	N／mm²	
15	A	623	344	270	本発明例
16	A	627	351	275	本発明例
17	B	523	320	260	本発明例
18	B	530	318	255	本発明例
19	C	683	360	295	本発明例
20	C	681	367	285	本発明例
21	D	523	315	255	本発明例
22	D	528	310	255	本発明例
23	A	620	243	220	比較例
24	B	532	224	205	比較例
25	C	675	264	235	比較例
26	E	340	110	—	比較例
27	G	613	286	225	比較例
28	H	691	321	210	比較例
29	I	625	347	195	比較例
30	J	681	362	195	比較例

[0030] Furthermore, various rolling-up temperature after hot-rolling was changed, and the effect to which rolling-up temperature does to the notch **** elongation of a steel plate was investigated. By the notch tension test, it is JIS. The tensile test was carried out to the crosswise both sides in the parallel part longitudinal direction mid gear of a No. 5 test piece using the test piece in which 45 aperture angles and a V notch with a depth of 2mm were formed. And ElV which asked for the elongation percentage to 5mm of gauge length containing a V notch after fracture of a test piece, and was obtained The value estimated workability. Results of an investigation are shown in a table 4. Test numbers 31-38 (example of this invention) are high ElV as compared with the test numbers 39 and 40 (example of this invention) to which steel A-D is rolled round, and it hot-rolls at the temperature of 600 degrees C or less, and rolls round by the same steel type, and temperature exceeds 600 degrees C. The value is shown and it turns out that it excels in local ductility. On the other hand, it is ElV even if it rolls round so that test numbers 43 and 44 (example of a comparison) may see, when the steel G and H with which are not satisfied of the component conditions specified by this invention is used, and temperature is 600 degrees C or less. The value is low. Moreover, at the test numbers 45 and 46 (example of a comparison) rolled round at the temperature which exceeds 600 degrees C, using the steel F and K with many C contents and Cr contents, it is ElV. The value was as low as 22% and 27%, and inferior to workability.
[0031]

表4：熱延巻取り温度が切欠き引張伸びに及ぼす影響

試験番号	鋼種記号	熱延巻取温度 ℃	切欠引張伸び El_v値 %	区分
31	A	580	38	本発明例
32	A	560	40	
33	B	580	41	
34	B	480	43	
35	C	580	35	
36	C	530	38	
37	D	580	40	
38	D	500	42	
39	A	630	34	
40	B	650	34	
41	C	680	29	
42	D	650	33	
43	G	580	34	比較例
44	H	580	29	
45	F	680	22	
46	K	650	27	

[0032]
[Example 2] The steel of the presentation shown in a table 5 was ingoted. Steel L-O is steel with which are satisfied of the component conditions specified by this invention, and [%P] <=6x[%B] +0.005. Among comparison steel P-U, although Steel P satisfies [%P] <=6x[%B]+0.005, C content is lower than the range specified by this invention. It is not satisfied with the point that Steel Q has high C content and Ti and B are not added of the conditions specified by this invention. Steel R is S35C of a JIS steel type, and is not satisfied with the point that Ti and B are not added of the conditions specified by this invention. Steel S is not satisfied with the point that there are many amounts of N and Ti and B are not added of the conditions specified by this invention. Steel T and U is steel with which are not satisfied of [%P] <=6x[%B]+0.005.
[0033]

表5：実施例2で使用した鋼材の種類

鋼種記号	合金成分及び含有量 (重量%)										X値	区分
	C	Si	Mn	P	S	Cr	Ti	B	Al	N		
L	0.36	0.04	0.33	0.011	0.005	0.29	0.02	0.0045	0.030	0.0035	0.032	本発明例
M	0.23	0.25	0.50	0.020	0.003	0.42	0.05	0.0033	0.022	0.0033	0.025	
N	0.48	0.01	0.34	0.009	0.008	0.11	0.03	0.0040	0.038	0.0024	0.029	
O	0.20	0.06	0.88	0.006	0.004	0.47	0.11	0.0008	0.027	0.0032	0.010	
P	0.12	0.33	0.52	0.011	0.006	—	0.05	0.0031	0.020	0.0034	0.024	比較例
Q	0.65	0.25	1.23	0.010	0.005	—	—	—	0.024	0.0030	—	
R	0.35	0.23	0.71	0.013	0.009	—	—	—	0.021	0.0033	—	
S	0.46	0.24	0.55	0.025	0.012	—	—	—	0.033	0.0280	—	
T	0.35	0.06	0.31	0.035	0.006	0.35	0.03	0.0036	0.030	0.0025	0.027	
U	0.45	0.08	0.44	0.017	0.007	—	0.03	0.0007	0.024	0.0260	0.009	

X値＝6×B＋0．005

[0034] The steel ingot which cast and obtained each molten steel was hot-rolled, and it considered as the hot-rolling plate of 4.0mm of board thickness. After holding a hot-rolling plate at 900 degrees C for soak 15 minutes, it held at 300-500 degrees C for 30 minutes, and was made the bainite texture. About a part of steel L-N, annealing of soak 20 hours was given at 700 more degrees C, and it was made the balling-up carbide organization. The front face of the test piece cut down from each steel plate was ground with the emery paper with which the yarn counts differ, and the sample which changed surface roughness was prepared. And after heat-treating under electron beam exposure conditions with a part [for the acceleration voltage of 60kV, the beam current of 70mA, the beam amplitude frequency of 1.5kHz, and exposure speed 4m/], and an exposure width of face of 10mm, visual observation of the crater-like surface discontinuity generated in the heat treatment section was carried out, and it asked for the crater-like surface-discontinuity generating number per unit area (/cm2).

[0035] At the test numbers 51-58 (example of this invention) which adjusted surface roughness to 0.5-4.7 micrometers of Ra as seen in the table 6 showing the relation between the surface roughness of a raw material steel plate, and the crater-like defective generating number, the crater-like surface-discontinuity generating number of the heat treatment section is 2 0-2 pieces/cm. It has become and the good front face was presented. On the other hand, at the test numbers 59-64 (example of a comparison) to which surface roughness was coarsely adjusted with 5.7-13.5 micrometers of Ra, the crater-like surface-discontinuity generating number of the heat treatment section is 2 9-17 pieces/cm. As compared with the example of this invention, remarkably, and it had become surface [poor].

[0036]

表6：素材鋼板の表面粗さがクレータ状表面欠陥に及ぼす影響

試験番号	鋼種記号	表面粗さRa μm	クレータ状表面欠陥の発生個数 個／cm^2	区分
51	L	4.0	2	本発明例
52	L	0.5	0	
53	M	3.3	1	
54	M	2.1	0	
55	N	4.7	2	
56	N	3.6	2	
57	O	1.4	0	
58	O	2.5	0	
59	L	6.0	10	比較例
60	L	9.4	15	
61	M	5.7	9	
62	N	7.8	11	
63	N	13.5	17	
64	O	7.3	9	

[0037] Furthermore, the test piece was heat-treated for the test piece cut down from each steel plate by the electron beam exposure with a part [for the acceleration voltage of 60kV, the beam current of 70mA, the beam amplitude frequency of 1.5kHz, and exposure speed 4m/], and an exposure width of face of 10mm, and the cross section hardness of the heat treatment section was measured. And the distance to the location blank test piece front face where the hardness equivalent to 80% of maximum hardness is obtained was measured, and it considered as the depth of a hardening layer. Moreover, after carrying out the electron beam exposure of front flesh-side both sides of a test piece on conditions with a part [for the acceleration voltage of 60kV, the beam current of 70mA, the beam amplitude frequency of 1.5kHz and exposure speed 4m/], and an exposure width of face of 30mm, the fatigue limit was measured by the same fatigue test as an example 1.
[0038] As compared with the test number 77 (the example of a comparison, steel R) of the almost same C content, the hardening layer was as deep as about 340 micrometers, and the fatigue property was also excellent in test numbers 65 and 66 (example of this invention) so that the results of an investigation of a table 7 might see. Although test numbers 67, 68, 71, and 72 (example of this invention) have C content as low as about 0.2 % of the weight as compared with 0.35 % of the weight of C contents of a test number 77 (the example of a comparison, steel R), the deep hardening layer is formed. Although C content of maximum hardness was almost equivalent at the test numbers 65-70 made into the bainite texture although test numbers 73-75 (example of a comparison) made steel L-N the balling-up carbide organization, respectively as compared with the thing of this level, raw material reinforcement was low, and since the hardening layer was shallow, moreover, fatigue strength was falling. Test numbers 69 and 70 (example of this invention) had the hardening layer as deep as 360 micrometers as compared with the test number 78 (the example of a comparison, steel S) of the almost same C content, and since there was also little crater-like surface discontinuity, the remarkably excellent fatigue property was shown. test numbers 79 and 80 (example of a comparison) any — [%P] <=6x [%B] the conditions of +0.005 are satisfied — not having — the test numbers 65 and 66 (example of this invention) with respectively almost same C content And test numbers 69 and 70 (example of

this invention) The fatigue limit is low although it has the hardening layer depth of the same level. In the test number 76 (example of a comparison), since there were few C contents than the minimum specified by this invention, the hardening layer was also shallow low, and maximum hardness is on a actual activity and caused trouble.
[0039]
表７：各鋼板の熱処理性及び熱処理後の疲労特性

試験番号	鋼種記号	熱処理で形成された硬化層		熱処理部の疲労限度 N/mm^2	区分
		最高硬さ, HV0.1	深さ, μm		
65	L	624	340	355	本発明例
66	L	617	338	350	本発明例
67	M	522	318	285	本発明例
68	M	529	316	275	本発明例
69	N	671	364	420	本発明例
70	N	679	373	430	本発明例
71	O	520	329	290	本発明例
72	O	518	318	280	本発明例
73	L	617	250	220	比較例
74	M	532	239	205	比較例
75	N	668	264	240	比較例
76	P	346	115	—	比較例
77	R	631	277	240	比較例
78	S	682	301	217	比較例
79	T	620	336	230	比較例
80	U	679	365	235	比較例

[Translation done.]